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# THE VIRGINIA JOURNAL OF SCIENCE

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# VIRGINIA JOURNAL OF SCIENCE

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**A Biometrical Analysis of Terminal Leaflet  
Characteristics of the North American  
*Cimicifuga* (Ranunculaceae)**

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ABSTRACT

Terminal leaflets of the compound leaves of the six species of North American Bugbanes are conspicuously distinctive morphologically. However, Eastern North American species may be mistaken for each other. Further delineation of the North American *Cimicifuga* (Ranunculaceae) is accomplished by statistical analyses of terminal leaflet anatomical characteristics such as lengths of stomatal apparatus and the number of stomates per  $0.1 \text{ mm}^2$ .

Terminal leaflet mean lengths, widths, and sinus depths set *Cimicifuga rubifolia* Kearney apart from the other two Eastern North American species, *C. americana* Michx. and *C. racemosa* (L.) Nutt.

INTRODUCTION

Although the terminal leaflets of the compound leaves of the six species of North American Bugbanes are quite distinctive morphologically, the Eastern North American species may be mistaken for each other especially when reproductive structures are unavailable for observation. *Cimicifuga rubifolia* Kearney, clearly a distinct species, has not been well understood by taxonomic botanists and is recognized as *C. racemosa* (L.) Nutt. Var. *cordifolia* (Pursh) Gray in commonly used manuals such as Fernald (1950) and Gleason (1963). Recent workers including Keener (1977), Wofford and Evans (1979) and Ramsey and Chester (1981) recognize *C. rubifolia* as a distinct species based primarily on Ramsey (1965). The two Northwestern United States species, *C. elata* Nutt. and *C. laciniata* Wats., may also be misidentified occasionally. Hasagawa (1970) has no mention of *C. arizonica* Wats. or *C. rubifolia* as distinct species.

In an effort to further delineate the taxa of North American *Cimicifuga*, a biometrical analysis of anatomical characteristics of the terminal leaflets was undertaken. The lengths of the stomatal apparatus and the number of stomates per unit area were studied in ten individuals of each taxon. Also, mean lengths, widths, and sinus depths of the terminal leaflets of the three Eastern North American species of *Cimicifuga* do reveal distinctive differences. No studies of this nature have been previously published for the genus.

## METHODS AND RESULTS

Using the method of Sinclair and Dunn (1961), impressions of the abaxial surface of fresh leaflets were made in Archer's Herbarium Plastic. The plastic layer was peeled from the leaflet surface upon drying and mounted under a cover glass for microscopic study. The length of the stomatal apparatus was measured in microns and the number of stomata per  $0.1 \text{ mm}^2$  of leaflet surface was counted on one plastic peel from each plant. The measurements were made at 1350X magnification and the counts at 675X magnification. A total of ten measurements and ten counts were obtained from each peel, resulting in 100 measurements and 100 counts for each of the six North American species.

The data (i.e., 1200 observations) were subjected to a two-factorial analysis of variance utilizing an IBM 740 Computer. Components of the analysis of variance table were obtained and an F Test performed which indicated a significant difference at the 99 per cent confidence level between several species for stomatal lengths and also in the number of stomata per  $0.1 \text{ mm}^2$  (Table I and II).

Table I. Comparison of all possible combinations of mean lengths of the stomatal apparatus for the North American Cimicifuga

Taxa Compared	Numbers of Species in the Range	Mean Values	Differences
D-B	6	60.59-42.76	17.83**
D-E	5	60.59-43.16	17.43**
D-F	4	60.59-43.21	17.38**
D-C	3	60.59-46.50	14.09**
D-A	2	60.59-47.92	12.67
A-B	5	47.92-42.76	5.16**
A-E	4	47.92-43.16	4.76**
A-F	3	47.92-43.21	4.71**
A-C	2	47.92-46.50	1.42*
C-B	4	46.50-42.76	3.74**
C-E	3	46.50-43.16	3.34**
C-F	2	46.50-43.21	3.29**
F-B	3	43.21-42.76	.45
F-E	2	43.21-43.16	.05
E-B	2	43.16-42.76	.40

\*\* Indicates a significant difference at ( $P \geq .01$ )

\* Indicates a significant difference at ( $P \geq .05$ )

Table II. Comparison of all possible combinations of mean numbers of stomata per  $0.1 \text{ mm}^2$  for the North American Cimicifuga

Taxa Compared	Number of Species in the Range	Mean Values	Differences
F-D	6	1.72- .89	.83**
F-A	5	1.72- .90	.82**
F-C	4	1.72-1.17	.55**
F-E	3	1.72-1.30	.42**
F-B	2	1.72-1.71	.02
B-D	5	1.71- .89	.82**
B-A	4	1.71- .90	.81**
B-C	3	1.71-1.17	.54**
B-E	2	1.71-1.30	.41**
C-D	4	1.30- .89	.41**
E-A	3	1.30- .90	.49**
E-C	2	1.30-1.17	.13
C-D	3	1.17- .89	.28**
C-A	2	1.17- .90	.27**
A-D	2	.90- .89	.01

\*\*Indicates a significant difference at ( $P > .01$ )

The mean values of 10 measurements of the stomatal apparatus from each of the 10 individuals of all six North American taxa were analyzed for significant differences by the Multiple Range Test proposed by Duncan (1955). The following results were obtained:

<u>C. ariz.</u>	<u>C. race.</u>	<u>C. rubi.</u>	<u>C. elata</u>	<u>C. amer.</u>	<u>C. laci.</u>
B	E	F	C	A	D
42.76	43.16	43.21	46.50	47.92	60.59

The mean values of 10 counts of stomates per  $0.1 \text{ mm}^2$  from each of the 10 individuals of all six North American taxa were analyzed for significant differences by the Duncan's Multiple Range Test. The following results were obtained:

<u>C. laci.</u>	<u>C. amer.</u>	<u>C. elata.</u>	<u>C. race.</u>	<u>C. ariz.</u>	<u>C. rubi.</u>
D	A	C	E	B	F
.89	.90	1.17	1.30	1.71	1.72

All means underscored by the same line show no significant differences in lengths of stomatal apparatus or number of stomata per  $0.1 \text{ mm}^2$ . All means not underscored by the same line have significant differences for the two characteristics involved.

The stomatal apparatus of Cimicifuga laciniata is shown to be significantly longer than those of the other North American species. The stomatal lengths of C. americana and C. elata are not significantly different from each other but are from the remaining species. C. arizonica, C. racemosa and C. rubifolia have stomates with essentially the same length, which is significantly different from that of the other species. Cimicifuga rubifolia can be distinguished from C. americana but not from C. racemosa on the basis of this analysis.

The analysis of the number of stomata shows that C. rubifolia has the greatest number per  $.1 \text{ mm}^2$  but is not significantly different in stomatal number from C. arizonica. However, these two species are significantly different from the other North American species for this character. C. elata and C. racemosa show no significant differences in number of stomates as is true, also, for C. laciniata and C. americana. On the basis of this analysis C. rubifolia can be distinguished from both C. americana and C. racemosa with which it is often confused. It is interesting to note that an eastern and western North American species have fallen into each of the non-significant categories shown.

The stomates of all six species discussed here are of the anomocytic (Ranunculaceous) type.

Measurements of terminal leaflet length, width, and depth of basal sinus were made on 251 specimens of C. rubifolia, 140 specimens of C. racemosa, and 55 specimens of C. americana. These measurements were used in an effort to further separate C. rubifolia from the other two eastern North American species. Results are shown in Table III.

In 99 per cent of the specimens identified as C. rubifolia a sinus was present with the depth ranging from 0.2 - 5.5 cm., with most depths being in the 1.5 - 3 cm. range. The mean terminal leaflet length measured 14.4 cm., the mean width 15.6 cm.

In 90 per cent of the specimens identified as C. racemosa there was no sinus. For those which have a sinus the depth was only 0.2 - 0.5 cm. The terminal leaflet of this species is rarely more than slightly subcordate, if at all. The mean terminal leaflet length measured 10.5 cm., the mean width 8.1 cm.

In 98 per cent of the specimens identified as C. americana there was no sinus. For those which have a sinus the depth was only about 0.5 cm. The terminal leaflet bases of this species are usually subcuneate. The mean terminal leaflet length measured 10.4 cm., the width 8.9 cm.

Upon using these characteristics it can be seen that C. rubifolia can usually be separated from the other two species on the basis of basal sinus depth and size of the leaflet which is in direct correlation with its shape. C. americana and C. racemosa cannot be distinguished from each other on the basis of these same characteristics.

Table III. Measurements of terminal leaflet, widths, lengths, and sinus depths for the three eastern North American species of Cimicifuga<sup>a</sup>

Species	No. Specimens measured	$\bar{X}$ Length	$\bar{X}$ Width	Sinus Depth
<u>C. americana</u> Michx.	55	10.4	8.9	98% no sinus (0.5)
<u>C. racemosa</u> (L.) Nutt.	140	10.5	8.1	90% no sinus (0.2 - 0.5)
<u>C. rubifolia</u> Kearney	251	14.4	15.6	99% 1.5 - 3.0 (0.2 - 5.5)

<sup>a</sup> All measurements in centimeters

## ACKNOWLEDGEMENTS

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**Prey Selection Experiments and  
Predator-Prey Size Relationships in Eastern Fence  
Lizards, *Sceloporus undulatus hyacinthinus*, From Virginia**

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**Abstract**

Adult eastern fence lizards, *Sceloporus undulatus hyacinthinus*, from central Virginia were tested experimentally to determine if they exhibited preferences when given choices of several types of prey. In experiment I lizards selected carabid beetles more often than grasshoppers and crickets, probably because the higher activity of the beetles elicited the predatory response quicker. In experiment II carabid beetles were selected 17 times more often than aposematically-colored, and apparently unpalatable, tiger beetles. A stomach content analysis of *S. undulatus* taken from a site similar to the one from which the experimental lizards were collected revealed that ants, lepidopteran larvae, true bugs, spiders and grasshoppers were the most frequently consumed prey. Only one beetle was eaten. Mean prey length was log-normally related to lizard snout-vent length. Linear regression analysis revealed that variation in snout-vent length explained 50% of the variation in log-prey size. There was no significant difference in size of prey consumed by adult males and females, although the latter average significantly larger in body size than the former.

**Introduction**

The study of prey preference in lizards is of ecological interest because predation can affect population dynamics, distribution and activity patterns, as well as community composition (Rissing, 1981). Reznick et al. (1981) suggest that most predators are born with specific preferences, rather than being "blank slates". Preference can be determined by field observation, stomach analysis and experiments with live prey. Stomach analysis can also give an idea of relative importance of prey species (Toliver and Jennings, 1975). Although the measurement of diet selectivity via stomach analysis is useful when stomach contents are compared with prey sampled from the same environment, it is accurate only when the prey-sampling procedure "sees" prey as a predator does (Maiorana, 1978). Determination of the importance of lizards as insect predators depends on knowledge of prey density and species.

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Vision plays an important role in prey selection in lizards of the group Ascalabota (e.g., Burghardt, 1964; Sexton, 1964), which includes sceloporines of the family Iguanidae. McClellan et al. (1943) and Ferner (1976) noted that Sceloporus undulatus feed by detecting movements a few feet away, then quickly dash a short distance and seize the prey. This hunting procedure is very efficient because it wastes little energy. This predatory behavior can be viewed as a series of decisions made to maximize net energy return (Rissing, 1981). To the predator, insects represent a package of energy proportional to the size of the prey item and the amount of energy expended to capture it (Pough, 1973).

We designed two series of experiments to determine if Sceloporus undulatus selects prey types based on visual patterns. We identified the prey types in a separate sample of fence lizards to determine if similar prey selection occurred in the field. In addition, we examined the relationships between predator size and prey size to test the hypothesis that larger lizards eat larger prey than smaller lizards.

#### Materials and Methods

We obtained the adult Sceloporus undulatus hyacinthinus used in the feeding studies from a population at a dump site 4.0 miles south of Ashland, Hanover Co., Virginia, from 0930 to 1500 EDT between September 13 and October 4, 1981. We captured lizards by hand or by noosing. Lizards were maintained in groups of two in three-gallon plastic containers, each of which had an inch of sand, a few sticks, and water. The containers were kept in an incubator at 28°C with a 12L:12D photoperiod. We captured in pitfall traps or by net selected examples of four insect families (Carabidae, Acrididae, Gryllidae, and Cicindelidae), all native to the lizard's habitat. Feeding trials were conducted in two ten-gallon aquaria lined with white paper on the outside and inside floor. Lamps, placed directly over the aquaria, allowed high visibility and provided heat.

We tested ten lizards individually on alternating days, six days a week, in groups of four and six. Trials took place from 0930-1300 EST from October 15 to November 20, 1981. In each trial, we placed a lizard in one of two lighted aquaria for a ten minute acclimation period with the air temperature at 31°-34°C. We assumed body temperatures approximated these values following the acclimation period. The lizard was confined to one-half of the aquaria by a clear glass plate for a two-minute observation period after a prey item was introduced to the other half of the aquaria. The barrier was then raised to begin a 10-minute trial period during which the lizard was allowed to react to the prey. Type of prey, capture time, consumption time and general observations were recorded for each trial. The observer remained as motionless as possible to avoid disturbing the lizards. Feeding trials for any one lizard occurred at 48 hour intervals with no feeding between trials. Results from five of the ten lizards which ate at least once were used.

In experiment I we presented each lizard with three insect types simultaneously. The prey were a ground beetle (Carabidae), a grasshopper (Melanoplus sp.) and a cricket (Gryllidae). Prey length of all types was similar, 12.9-15.0 mm. In experiment II we presented each lizard with a ground beetle (Carabidae) and a tiger beetle Cicindela rufiventris. A four day starvation period occurred between experiments I and II. During testing, one lizard died and its data were discarded. This left four lizards to be tested six times each. Cicindelid elytra were glued together to prevent them from flying out of the arena.

Stomach contents of 27 S. undulatus collected from another dump site were examined for comparison with preference results. We captured these lizards 1.5 mi S of Seven Pines, Henrico Co.,

Virginia in July and September 1978 and May 1979. Snout-vent length (SVL) was measured to the nearest mm and sex was determined by internal examination. The type, volume, and number of prey eaten were recorded for each lizard. Stomach content volume was obtained by water displacement using a graduated cylinder. Length was taken on all intact prey. Insect taxonomy herein follows Borrer et al. (1979). Statistical analyses follow Zar (1974) and were performed using SPSS programs (Nie et al., 1975). Non-parametric tests were used where assumptions of heterogeneity and normality were not met. Means are followed by  $\pm$  one standard deviation.

### Results

In the twenty trials in experiment I carabids were first selected ten times, acridids three times and gryllids no times. There were seven trials in which no reaction was recorded. The difference of preference between carabids and acridids is only marginally insignificant ( $\chi^2 = 3.77$ ,  $P = 0.053$ ). Mean capture time for carabids  $134.2 \pm 171.2$  seconds,  $N = 10$  was only slightly lower than for acridids  $150 \pm 52.2$  seconds,  $N = 3$  and is not significantly different (t-test,  $t = 0.15$ ,  $P > 0.1$ ). In experiment II carabid beetles ( $\bar{x}$  length =  $12.5 \pm 0.5$  mm) were preferred over tiger beetles ( $\bar{x}$  length =  $12.1 \pm 0.5$ ). In the 24 trials of experiment II, 17 carabids and only one cicindelid were eaten. There were seven cases of no reaction. Average carabid capture time was  $124.7 \pm 182.7$  seconds and average handling time was  $56.5 \pm 101.7$  seconds. The only tiger beetle eaten was taken after a carabid had been consumed. It appeared to be difficult to handle as the lizard shook its head violently to subdue the beetle. Handling time was 330 seconds and only half the tiger beetle was consumed.

The sample of 27 *S. undulatus* (SVL =  $54.5 \pm 11.5$  mm, 23.5 - 71.5 mm) utilized for the analysis of diet and predator-prey size relationships contained twelve adult males ( $\bar{x}$  SVL =  $55.0 \pm 6.9$  mm, 43.0-62.0 mm), ten adult females ( $\bar{x}$  SVL =  $62.6 \pm 4.7$  mm, 57.0-71.5 mm) and five juveniles ( $\bar{x}$  SVL =  $36.0 \pm 9.6$  mm, 23.5-45.5 mm). The difference in SVL between adult males and females is significant (Mann-Whitney U test,  $U = 21.0$ ,  $P = 0.016$ ). Ants (Formicidae) were the most frequently selected food, followed by arachnids and lepidopteran larvae (Table 1). Lepidoptera (predominately larvae) and Orthoptera (mostly cockroaches) were the most important food items volumetrically. Carabids and acridids were represented samples but not gryllids or cicindelids, and they were found only in the September sample.

The mean prey size difference between adult males ( $7.37 \pm 3.73$  mm,  $N = 9$ ) and adult females ( $9.28 \pm 3.61$  mm,  $N = 9$ ) was not significant (Mann-Whitney U test,  $U = 24.0$ ,  $P = 0.145$ ). Mean prey length for juveniles was  $3.76 \pm 2.33$  mm ( $N = 5$ ).

The sample size for the regression analysis is 24 because two lizards contained only nematodes and another had an empty stomach. Mean prey length is log-normally related to SVL<sub>2</sub> (Fig. 1). Regression analysis using log-mean prey length vs SVL ( $r^2 = 0.496$ ,  $Y = -0.1473 + 0.0181\text{SVL}$ ) increased the fit of the regression line by 23.1% over the analysis using untransformed prey length ( $r^2 = 0.265$ ,  $Y = -5.663 + 0.260\text{SVL}$ ).

### Discussion

A basic assumption in these experiments is that the predators tested were all equally hungry and that hunger levels were the same on each test day (Charnov, 1976). Our testing protocol was designed to avoid this problem and there did not appear to be any major differences in responses among lizards. A second potential problem in lizard feeding experiments is that the lizards and/or the prey are of unequal sizes. As shown below, predator size may influence the size of the prey selected. We avoided this problem

by using all adult lizards and prey of similar sizes when testing each lizard.

In our experiments, the selection of carabid beetles more often than tiger beetles, grasshoppers and crickets by S. undulatus may have been due to several things. Predatory responses of many lizards are elicited by prey movement (Woodbury, 1932; Burghardt, 1964; Goodman, 1971; Cooper, 1981). The lizards in our experiments may have cued on the carabids because they moved actively and continually in the study containers. Grasshoppers and crickets were typically sedentary during the trials. Tiger beetles are highly mobile insects but may have been avoided in favor of the carabids because they can release noxious chemicals when disturbed (Blum et al., 1981). Fence lizards may be able to avoid these insects by recognizing their bright coloration, although Pritchett (1903) found that S. undulatus consumed several species of noxious and aposematically-colored insects, arachnids and scorpions, as well as cryptic ones. She found that most of the insects rejected were those which the lizard first tried to eat but found too distasteful. Insects which remained immobile were not consumed until she moved them. Thus, motion is a very important factor in eliciting the feeding response in S. undulatus. Whether or not they can discriminate between aposematically-colored and cryptically-colored prey remains to be conclusively determined.

In the sample of S. undulatus examined for stomach contents, ants and lepidopteran larvae were the most numerous prey types consumed, while Lepidoptera (mostly larvae), true bugs, spiders and tettigonid grasshoppers contributed the greatest volume. Ants were the most numerous prey of fence lizards studied by other authors (e.g., Cagle, 1945; McClellan et al., 1943; Toliver and Jennings, 1975). The numbers and volume of various prey types we observed were similar to other studies (e.g., Johnson, 1966; Smith and Milstead, 1971; Toliver and Jennings, 1975). Carabid beetles have seldom been reported as prey for fence lizards, whereas grasshoppers are commonly reported as prey. Both of these prey types were present only in our late-season sample. It is not likely, therefore, that a seasonal change in prey preference affected prey choice. This supports the contention that beetles were selected more often than orthopterans in our experiments because of their elicitation of the predatory response by their higher levels of activity.

Despite the sexual size dimorphism between adult males and females, there was no significant difference between actual prey size consumed in our samples. The lack of significant difference in prey size consumed by males and females has been reported for several lizard species (Schoener et al., 1982). However, significant differences between sexes with respect to prey size has been reported by several others (Schoener, 1967, 1968; Andrews, 1979; Simon, 1976; Powell and Russell, 1984). Sample size may play a role in whether differences are found because our results and those in Schoener et al. (1982) are based on smaller samples than in other studies.

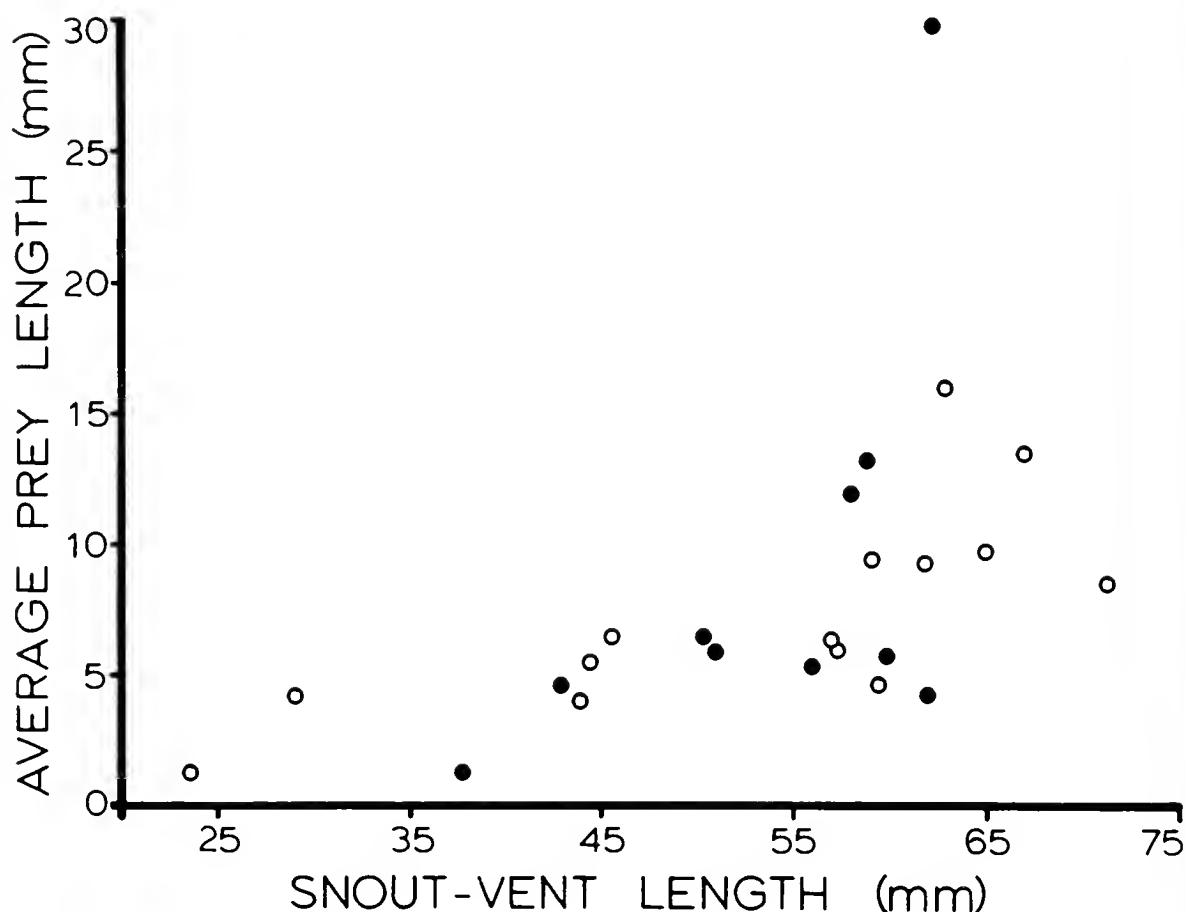
Although there is a strong correlation of prey length with predator SVL, the variation about the regression line is large. Only 50% of the variation is explained by the model. This suggests that other factors, such as prey availability and hunger level, strongly influence the size of prey a lizard selects. One of the largest lizards consumed a prey item much larger (30.0 mm) than other lizards in the sample (range = 1.5-16.0 mm). Presumably, a small lizard could not consume such large prey. The data in Fig. 1 suggest this may be an extreme case. Most of the larger lizards consumed prey considerably smaller. Results in other studies of predator-prey size relationships in S. undulatus (Toliver and Jennings, 1975) and in other lizards (Simon, 1976; Best and Gennard, 1984; Brooks and Mitchell, unpubl.) indicate large lizards eat a variety of different sized prey but most often only relatively small ones. Positive predator-prey size relationships

only appear when the sample contains small lizards with small prey and large lizards with very large prey at the extremes. The theory that large predators should consume only large prey for maximal energetic benefit (i.e., that they are foraging optimally (Pough, 1973)) is not supported for S. undulatus by our results. Nevertheless, the hypothesis that larger lizards consume larger prey than smaller lizards is generally supported by our results.

Table 1. Stomach contents of Sceloporus undulatus (N=26) from Henrico County Virginia. N is the number of lizards, no. is the number of prey and vol. is the volume of each prey category in ml.

Prey category	N	no.	% no.	vol.	% vol.
<u>Insecta:</u>					
Coeloptera					
Buprestidae	1	1	0.62	0.10	1.71
Carabidae	1	1	0.62	0.03	0.51
Chrysomelidae	5	5	3.13	0.23	3.93
Curculionidae	2	2	1.25	0.10	1.62
Elateridae	1	1	0.62	0.08	1.37
Staphylinidae	1	1	0.62	0.01	0.17
unknown family	1	1	0.62	0.01	0.17
Diptera					
Calliphoridae	1	1	0.62	0.05	0.85
unknown family	4	6	3.75	0.23	3.84
Hemiptera					
Pentatomidae	1	1	0.62	0.30	5.13
unknown family	3	7	4.38	0.66	11.28
Homoptera					
Cicadellidae	1	1	0.62	0.01	0.17
Hymenoptera					
Formicidae	17	79	49.38	0.07	1.25
Lepidoptera					
Heterocerlidae	1	1	0.62	0.54	9.23
larvae	10	15	9.38	1.45	24.69
Orthoptera					
Acrididae	1	1	0.62	0.20	3.42
Blattidae	4	5	3.13	0.33	5.64
Tettigoniidae	3	3	1.88	0.54	9.14
unknown family	1	1	0.62	0.26	4.44
<u>Other Invertebrates:</u>					
Arachnida	10	21	13.13	0.59	10.08
Diplopoda	4	5	3.13	0.03	0.51
Gastropoda	1	1	0.62	0.03	0.51
Nematoda	2	25 <sup>a</sup>		0.02	0.34
Totals		160	99.98	5.85	100.00

<sup>a</sup> not included in total



**Figure 1.**

Relationships of average prey length with lizard snout-vent length in the Henrico sample of *Sceloporus undulatus*. Black dots are males and open circles are females. Each dot represents one observation.

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## Transmission of Peanut Mottle Virus by Three Aphid Vectors from Peanut to Peanut in the Laboratory

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### Abstract

The transmission of peanut mottle virus (PMV) from peanut to peanut in the lab by Myzus persicae, Aphis craccivora and Rhopalosiphum maidis was 29, 14, and 4 percent, respectively, using five aphids per test plant, and was lower than had been previously reported. M. persicae was the most efficient transmitter of PMV in this series of tests. PMV was transmitted at a rate of 7.5 percent when using 14 day old peanut seedlings as the virus recipient, and 2.3 percent when using 28 day old seedlings as the virus recipient. The retention period of PMV by the species of aphids tested was between one and 15 minutes.

Key Words: Peanut mottle virus, aphids, Myzus persicae, Aphis craccivora, Rhopalosiphum maidis, peanuts, Arachis hypogaea, virus transmission.

### Introduction

Peanut mottle virus is a disease agent of peanuts that is worldwide in distribution. This disease is prevalent in the southeastern U.S. peanut growing region, and was relatively rare in the Southwestern U.S. in the early 1970's (Demske et al 1975). The extent of infection in Virginia peanuts is unknown, however, it appears to be quite common in Virginia soybean fields (Tolin and Polstan 1978).

PMV spread leading to natural field epidemics is attributed to several species of aphids, and reported vectors include Aphis craccivora Koch, Myzus persicae (Sulzer), Rhopalosiphum maidis (Fitch) and Hyperomyzus lactucae (L.) (Behncken 1970; Bock 1973; Highland et al 1981). Little detailed information is available about the relative ability of these aphids to transmit PMV from peanut to peanut. Previous workers have used the peanut cultivar Starr in transmission studies (Paguio and Kuhn 1976). No work has been done on the transmission of PMV using Florigiant, the predominant peanut variety grown in Virginia.



Previous work has shown that different strains of PMV will be transmitted at different rates by different aphid vectors (Paguio and Kuhn 1976). These tests were conducted using A. craccivora and M. persicae. Very little work has been done with R. maidis, a frequently abundant aphid reproducing on corn, a crop often planted near peanut fields. The purpose of this study was to determine the relative abilities of M. persicae, A. craccivora, and R. maidis to transmit a Virginia isolate of PMV using the Florigiant variety as the viral source and test plant.

## Methods and Materials

### Virus Source and Aphid Colonies

PMV V74S-473, an isolate of the virus recovered from an infected soybean plant in the Tidewater area of Virginia (S. A. Tolin, personal communication<sup>1</sup>), was used in all transmission tests. On peanuts, the isolate induces mild mottle symptoms.

The virus was maintained on Essex soybeans at the VPI&SU greenhouse in Blacksburg, and was mechanically inoculated onto Florigiant peanut seedlings. This was accomplished by grinding 1.0g infected soybean leaves in 2.0 ml. of a 0.01M sodium phosphate buffered solution, pH 8, and rubbing the infected sap using cotton gauze pads onto peanut seedlings in the 3-6 true leaf stage. Carborundum was dusted on the leaves prior to rubbing to facilitate infection. Virus symptoms were observed 14 days after hand inoculation. All suspect PMV infected peanut seedlings were assayed for PMV by mechanically inoculating Topcrop bean (Phaseolus vulgaris). Topcrop seedlings were inspected every other day for up to 14 days after inoculation for characteristic reddish-brown necrotic local lesions indicating positive PMV infection. Seven days is the appropriate time period between mechanical inoculation with PMV and symptom expression. PMV infected peanuts that indexed positive on Topcrop were used as reservoirs for the virus transmission studies.

A. craccivora were collected from fava beans (Vicia faba) growing in the greenhouse, R. maidis were collected from sorghum (Sorghum bicolor) growing near Blacksburg, Virginia, and the M. persicae were obtained from a colony being maintained in the greenhouse on chinese cabbage (Brassica chinensis)<sup>2</sup>. Aphid colonies were reared on their respective hosts in glass and organdy covered wooden cages in the greenhouse. A. craccivora were maintained on cowpea (Vigna unguiculata (L.) Walp. subsp. unguiculata cv. California Blackeye, M. persicae on Chinese cabbage cv. Wong Bok, and R. maidis on field sorghum cv. 126-DR-5 sweet sorghum.

### Transmission of PMV by Aphid Species

Aphids were starved for 4-6 hours in glass vials and then allowed access to PMV infected peanut leaflets for 5 minutes using 1 aphid per test plant, or 15 minutes using 5 aphids per test plant. Starvation and access time periods were set based on work done by Zettler and Wildinson (1966) who showed that starved M. persicae increased their probing time of host plants over non-starved aphids, and M. persicae that were allowed many uninterrupted probes on the virus source may be more likely to transmit a stylet-bone plant virus (bean common mosaic virus) than those allowed only one probe. Activity of the aphids was monitored with a stereomicroscope during access periods to ensure contact of

the insect's labium tip with the leaf surface. Stylet insertion into the plant tissue was assumed. After access periods 1 or 5 aphids were transferred to each virus free peanut seedling, which were either 10-14 days old (seedling leaves open but not fully expanded), or 21-28 days old (first set of leaves fully expanded, second set unfolded but not fully expanded). The seed lots used were screened for PMV infected seed by examining 500 Florigiant seedlings grown from the seed lot for symptoms of PMV. No PMV infected seed<sup>3</sup> were detected, (David Bays, personal communication)<sup>3</sup>.

The test seedlings with aphids were held in the greenhouse undisturbed for 12-17 hours, after which time the aphids were destroyed. The peanut seedlings were inspected after 21 days for PMV symptoms. Test seedlings showing any visible symptoms of PMV infection were assayed using Topcrop beans. Red lesions on Topcrop indicated PMV infection. A series of tests using one aphid per test plant were conducted using the Florigiant variety for the virus source and as test plants, and at least 20 tests using one aphid per test were conducted per aphid species.

#### Retention Time Tests

Retention time tests involved starving the aphids for 4-6 hours, allowing them an access time period of five (5) minutes on an infected peanut leaflet, and then removing and isolating them for one (1) minute, fifteen (15) minutes, thirty (30) minutes, one (1) hour, and two (2) hours, before allowing them access to a virus free seedling for 12 hours. One aphid was used per test seedling. After the inoculation

**Table 1.** Transmission of PMV using five aphids per test plant and Florigiant peanut variety.

Aphid	No. Plants Infected /No. Tested <sup>a</sup>	Percent Transmission <sup>b</sup>
<u>M. persicae</u>	5/17	29.4a
<u>A. craccivora</u>	4/29	13.79ab
<u>R. maidis</u>	1/27	3.70b

<sup>a</sup> Peanut seedlings exposed to viruliferous aphids 10-14 days post-emergence.

<sup>b</sup> Values in the same column followed by different letters are significantly different at 5% level according to Fisher's exact test.

time period, the aphids were destroyed, and the test seedlings held for 21 days and examined for symptoms of PMV. Seedlings showing PMV symptoms were assayed to Topcrop bean.

### Results

In tests using five aphids per test plant, M. persicae transmitted PMV at the rate of 29.41%, A. craccivora at 13.79%, and R. maidis at 3.70%. M. persicae transmitted PMV at a significantly higher rate than R. maidis (Table 1).

Subsequent tests of the relative abilities of these aphids to transmit PMV using one aphid per test seedling showed percent transmission to be low for all three species when compared to previous results (Paguio and Kuhn 1976). M. persicae again transmitted PMV at a significantly higher rate than did R. maidis (Table 2). When segregating the

**Table 2.** Transmission of PMV using one aphid per test plant and Florigiant peanut variety.

Aphid	No. Plants Infected /No. Tested	Percent Transmission <sup>a</sup>
Peanut Seedling Exposed to Viruliferous Aphid 10-14 Days Post Emergence:		
<u>M. persicae</u>	6/41	14.63a
<u>A. craccivora</u>	5/65	7.69ab
<u>R. maidis</u>	0/41	0b
Peanut Seedling Exposed to Viruliferous Aphid 21-28 Days Post Emergence:		
<u>M. persicae</u>	2/52	3.85a
<u>A. craccivora</u>	0/68	0a
<u>R. maidis</u>	2/52	3.85a

<sup>a</sup>Values in the same column followed by different letters are significantly different at the 5% level according to Fisher's exact test.

results according to age of the test plants, more positive transmissions were achieved with younger seedlings (10-14 days old after planting). In transmission tests using Florunner variety, only one of twenty PMV transfer was observed for the three aphids tested.

The retention abilities of these aphids appears to be low. The only positive retentions occurred for M. persicae and A. craccivora, both at the one (1) minute period. R. maidis was not able to retain infectivity for any time period tested (Table 3).

**Table 3.** Retention of PMV by M. persicae, A. craccivora, and R. maidis at Varying Time Intervals.<sup>a</sup>

Aphid	Retention Period (Minutes)				
	1	15	30	60	120
<u>M. persicae</u>	2/26 <sup>b</sup>	0/20	0/10	0/10	0/15
<u>A. craccivora</u>	1/45	0/10	0/10	0/10	0/10
<u>R. maidis</u>	0/20	0/10	0/14	0/10	0/10

<sup>a</sup>None of the values were significantly different at the 5% level according to Fisher's exact test.

<sup>b</sup>Number of plants infected per number tested.

### Discussion

All three aphid species tested are able to transmit PMV 74S-473 from peanut to peanut using Florigiant as the virus source and test plant. M. persicae appears to be the most efficient vector, followed by A. craccivora and R. maidis, although M. persicae and A. craccivora were not statistically separable. Differences in probing behavior could account for the differences in transmission ability by these three aphid species. The importance of the aphid composition in the epidemiology of peanut mottle disease in peanut fields cannot be underestimated. A. craccivora and M. persicae were trapped in large numbers in a peanut field in which peanut mottle disease spread was observed (Highland et al. 1981). These aphids must be suspected as the primary vectors of PMV in heavily infested peanut fields. In order to limit spread of the virus, populations of M. persicae and A. craccivora should be restricted near peanut fields, especially seed peanut producing fields, in areas of PMV infection.

Paguio and Kuhn (1976) found that M. persicae and A. craccivora transmitted four strains of PMV with much greater efficiency than was exhibited here with strain 473. In their work, M. persicae was able to transmit four strains of PMV at the rate of 16 to 54%, and A. craccivora was found to be able to transmit the same strains of PMV at the rate of 9 to 32%. The transmission techniques used in the present study, and by Paguio and Kuhn were similar, however, Paguio and Kuhn used the Starr variety, while this study used Florigiant. Paguio and Kuhn used strains of the virus recovered from Georgia, while this study used a different strain of the virus recovered from Virginia. Different aphid populations were also used in these two studies. Any of these factors could explain the difference in results. The difference seen in the transmissibility of the different strains of the virus could account for the apparent prevalence of the disease in some peanut producing areas and not others. PMV 74S-473 could exist at low levels in many Virginia peanut fields, but the reduced ability of the aphids to transmit this isolate of the virus could be the reason why the disease is not readily apparent in some Virginia peanut growing regions. Tests using a common aphid population and peanut variety, but with different isolates of PMV recovered from different geographical areas, would have to be performed to test the effect of PMV isolates on apparent infection in the field.

The extent to which the M. persicae and A. craccivora are present through the Virginia peanut growing region is not known at this time. These are, however, two common aphids that can reproduce on a number of host plants, and they probably exist in substantial numbers throughout the peanut growing area of Virginia.

The age of the peanut plant during aphid inoculation with PMV could be an important factor to consider in the spread of this disease through commercial plantings. Younger seedlings are more readily infected with PMV by aphids. Chemicals which might be directed against the aphid vectors of PMV, such as oils or insecticides (Simmons and Zitter 1980) should be applied when peanut seedlings are young, in order to protect the more susceptible stages of the developing peanut plant. Historically the use of insecticides or oils to reduce stylet-borne virus infection in field crops has been unreliable, and the most practical control solution could be a good seed certification program.

Transmission rates of PMV 473 do not appear to increase when the source of inoculum and test plants are switched from Florigiant to Florunner. Florunner is the predominant variety grown in the southeastern U.S., while Florigiant is the predominant variety grown in Virginia. Varietal differences do not appear to be the reason for the apparent difference seen in PMV infection between the two areas. More tests using different varieties need to be done before definite conclusions can be drawn concerning the effect of peanut variety on PMV transmission by aphids.

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### Footnotes

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## **The Effect of Methyl Bromide-Chloropicrin Soil Fumigation on Strawberry Yields**

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### **ABSTRACT**

The average yield for three June-bearing strawberry cultivars (*Fragaria x ananassa* Duch.) was increased the first year by 8% following soil fumigation with 98% methyl bromide-2% chloropicrin applied in the fall prior to spring planting. Yields for the second fruiting season from the same plants averaged 5% higher in fumigated plots, but differences were not significant. Fumigation increased yields of 'Brighton' and 'Hecker', day neutral cultivars from California, by 74% during spring harvest, but yields were too low for commercial production.

### **INTRODUCTION**

Soil fumigation has been shown to be effective in reducing nematode and weed populations in strawberry plantings, along with controlling soil-borne insects and the fungi that cause *Verticillium* wilt and red stele root rot (Masui et al., 1979; Wilhelm and Paulus, 1980). Soil fumigation is standard cultural practice in California and Florida where strawberries are grown as an annual crop. Yield increases in response to soil fumigation in California have been 35% for the standard 2:1 methyl bromide-chloropicrin, 26% for methyl bromide alone and 45% for chloropicrin alone. Average fruit size was increased by 7% for the 2:1 combination or with methyl bromide alone, and 10% by Chloropicrin alone (Voth et al., 1977). In Florida, fumigation with 69% methyl bromide gave a 31% yield increase, while 67% methyl bromide - 33% chloropicrin showed an 81% increase, and Vorlex treatment gave a 27% increase (Locascio and Smart, 1968). The use of Vorlex in West Virginia increased yields by 22% over controls (Keefer et al., 1978). Pre-plant soil fumigation in Arkansas with methyl bromide resulted in an average yield increase of 23% and an average fruit weight increase of 16% for the 46 strawberry cultivars tested (Moore et al., 1979). Twelve June-bearing cultivars were compared under 67% methyl bromide - 33% chloropicrin at 429 kg/ha (383 lb/A) and non-fumigated conditions on a site where strawberries had not grown previously in Kentucky. Fumigation significantly increased overall yields 9% the first harvest season, but not the second. 'Surecrop' was the only cultivar which significantly responded to fumigation (Strang et al., 1985). Little information is available on the benefits of fumigation under temperate east coast climates and heavy soil conditions. The purpose of this study was to evaluate the response of 5 strawberry cultivars to soil fumigation under western Virginia conditions.

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## MATERIALS AND METHODS

A field experiment was conducted at the VPI & SU Horticulture Farm, Blacksburg, VA in a 2 x 5 split plot design. Whole plots consisted of control and soil fumigation treatments which were each replicated 4 times. Sub plots consisted of 3 meter row sections of the following 5 cultivars: 'Guardian', 'Scott', 'Vesper', 'Hecker', and 'Brighton' each of which was replicated 15 times. The land had been planted in vegetable crops prior to the study and was well cultivated to a 20 cm depth prior to fumigation. Soil temperature at the time of fumigation at depth of 15 cm was 18°C. and soil moisture was adequate. Plots were fumigated in September 1979, with 258 kg per hectare (230 lb/A) 98% methyl bromide and 2% chloropicrin and covered with a 1 mil plastic tarp for 2 months. The following spring, plants were set 61 cm apart in rows which were 91 cm apart, and allowed to establish a matted row. Yield data were collected in the spring of 1981 and 1982. Soil and root samples were obtained in August, 1981, and analyzed for nematode types and population. Plots were also rated for weed populations on two dates in 1980 and 1981. Standard commercial fertilizer, herbicide, and pesticide recommendations for Virginia were followed (Stiles and O'Dell, 1982).

## RESULTS AND DISCUSSION

Yield data for the first two harvest seasons after fumigation are presented in Table I. In 1981, yield increase in response to fumigation ranged from a low of 4% for 'Vesper' to a high of 99% for 'Brighton', while 'Guardian', 'Scott', and 'Hecker' showed increases of 16, 6, and 49%, respectively. The average berry weight was significantly increased only in 'Hecker' in response to treatment. Of the different cultivars tested, 'Scott' gave the greatest yield. The two California day-neutral cultivars 'Hecker' and 'Brighton' had the lowest yields. The low yields of these two cultivars would make them questionable for commercial use under VA conditions. Yields for the day-neutrals were not taken in 1982 because of poor plant populations attributed to winter injury.

Yields in 1982 for the three June-bearing cultivars showed no significant increase in response to fumigation. Yields for 'Guardian' were essentially identical while fumigated 'Scott' and 'Vesper' each showed an 8% increase over controls. There were no differences in average berry weight in response to treatment for any of the cultivars. The average yield increase of only 9% and 8% for the three June-bearing cultivars tested would suggest that the use of custom fumigation is cost-prohibitive.

The 230 lb per acre rate used in the current study is near the maximum label rate of 245 lb of 98-2 fumigant for fruiting strawberries. The use of 67% methyl bromide - 33% chloropicrin at a maximum rate of 350 lbs. of product per acre might provide additional responses on heavy soil types. The significant yield responses obtained by Moore et al. (1979) with methyl bromide were at a substantially higher rate of 435 lb per acre.

In view of these typical yield increases from other states, our 8% increase is far below the average. Possible explanations for this small response include the heavy silt loam soil type, insufficient fumigation at the depth preparation of the seedbed, or recontamination of the soil. Additional factors such as soil temperature and moisture along with cultural practices may also greatly influence soil fumigation responses.



Table 1. The Effect of Methyl Bromide-Chloropicrin Soil Fumigation<sup>z</sup> on the Yield of Five Strawberry Cultivars in 1981 and Three Cultivars in 1982.

Cultivar	1981		1982		1981		1982	
	Yield (kg/ha)		Yield (kg/ha)		Weight/berry (gm)		Weight/berry (gm)	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
<u>June-bearers</u>								
Guardian	11638a	13539a <sup>y</sup>	16922a	16970a	10.5a	10.3a	13.6a	13.5a
Scott	20652a	21901a	15554a	16798a	11.1a	10.9a	13.8a	13.6a
Vesper	13882a	14408a	14022a	15147a	14.7a	15.6a	18.0a	18.3a
<u>Day Neutrals</u>								
Hecker	6788a	10100b			7.4a	8.5b		
Brighton	2717a	4687b			10.8a	9.6a		

<sup>z</sup>258 kg per hectare (230 lb./acre) applied September, 1979.

<sup>y</sup>Mean separation in rows of data pairs by t-test at 5% level.

Table 2. Weed Control Ratings for Methyl Bromide-Chloropicrin Soil Fumigation Treatment in Strawberries in 1980 and 1981.

Date	Weed Control Rating <sup>2</sup>			
	Broadleaves		Grasses	
	Control	Fumigated	Control	Fumigated
6/22/80	7.6	8.5	8.1	9.1
9/20/80	5.4	5.6	5.9	7.3
6/15/81	7.7	8.8	8.4	8.5
9/16/81	7.6	7.6	6.2	7.5

<sup>2</sup>Rated on a scale of 1-10 with 1= no control and 10= total control, with 7= commercially acceptable control.

Plots were also scored for weed control on two dates during 1980 and 1981 using a scale of 0 to 10, where 0 is no effect on weeds and 10 is complete control (Table 2). The scoring of weed control in the plots was complicated by the fact that weed seeds apparently washed into the plots due to the sloping topography of the field. Additionally, the scoring of weed control in the plots in 1981 reflects the use of 8 lb. of Devrinol in late fall in 1980 and 1/2 lb. of Sinbar at postharvest renovation in 1981 in all plots. The use of fumigation under these conditions showed only a very limited weed control response, which could not justify the expense.

Analysis of nematode populations showed an average of about 75 Pratylenchus (lesion) and 25 Tylenchorhynchus (stunt) nematodes per 250 cm<sup>3</sup> of soil in control plots, while treated plots average 10 Pratylenchus. Other genera such as Hoplolaimus (lance) and Paratylenchus (pin) were also found in small numbers. Pratylenchus averaged about 25 per gram of roots in control plots and near zero in treated plots. Small numbers of Xiphinema (dagger) nematodes were occasionally found in root samples. There have been many other genera and species of nematodes which have been found in association with strawberries (Brown, 1958). The Pratylenchus population was near an economic level where soil fumigation might be recommended.

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**Virginia Academy of Science  
Council Meeting  
Minutes: March 15, 1986**

1. The Council met in Chandler Hall on the campus of James Madison University in Harrisonburg, VA. The meeting was called to order by President Bass at 1:20 p.m. Present: R. Bass, M. Bass, H. Bell, B. Bruner, A. Campbell, D. Decker, R. Duncan, J. Murray, D. Ramirez, V. Remsburg, C. Sellars, B. Silver, G. Taylor, G. Trelawny and D. Ulrich.

President Bass announced the death of the Vice President of Student Affairs at U of R, Bill Leftwich (brother of immediate VAS Past President Frank Leftwich) on March 14 and stated that the funeral would be held in Richmond on March 17.

2. The minutes of the last meeting on November 10, 1985 were approved as distributed.

3. Reports of Officers

President - President Bass reported on his activities since November 1985. (attached)

President-Elect - J. Murray reported on the preparation of the program for the May VAS meeting. He stated that the President of the University of Virginia has been contacted about an invitation for the 1988 Annual Meeting to be held at UVA. It was motioned by J. Murray that Council approve funding of incidental expenses for a symposium sponsored by the Biology Section at the VAS meeting in May. The title will be Vertebrate Life Histories in Virginia. He stated that this proposal would seem to be an appropriate response to Dr. Leftwich's call for initiatives from the section. M. Bass seconded the motion and it was approved by Council. It was suggested that this expense should be covered by the May meeting expenses and then if the Finance Committee so recommends it should be made a line item in the next year's budget.

Secretary - Attached is the report of the Executive Committee held on March 15, 1986.

Treasurer and Executive Treasurer - It was stated that the new dues structure seems to be working well (one complaint only) and at this point the paid membership is ahead of last year. A discussion was held concerning the expiration of the liability insurance carried by VAS. The pros and cons of the need of such insurance, as well as, its lack of availability were discussed. It was recommended that E. Thompson (AAAS representative) be asked to contact AAAS about their liability insurance coverage and any availability of such.

Past President - No report.

4. Local Arrangements Committee - G. Trelawny gave a brief review of the preparations that have been made for the May meeting. It was announced that Dr. Robert Parker, NASA astronaut, will be the speaker for both the VJAS and VAS meetings in May. Dr. Parker was a mission specialist aboard STS-9/Spacelab-1 launched in 1983 and was scheduled to be a member of the Space Shuttle 61-E/ASTRO-1 crew which was to be launched in March 1986. D. Ramirez stated that the Statistics Section will have 6-10 guests who will speak at a special symposium during the VAS May meeting and he requested an information packet concerning JMU and the Harrisonburg area to send to these individuals. It was suggested that the names be given to the Harrisonburg Chamber of Commerce for information mailing.

## 5. Section Reports

Statistics - This section will have 26 papers presented at the May meeting, as well as, a symposium with invited speakers from U.S., Japan & Canada.

Psychology - Attached report was received by mail.

Others - All of the other sections had no report.

## 6. Representative to AAAS - No report.

7. Visiting Scientists Program - H. Bell stated that all college presidents have been contacted concerning participation of their schools in this program.

## 8. Standing Committees

a. Awards - V. Remsburg made a report (attached) for the Awards Committee which contained a recommendation for approval as a Fellow of VAS. The Council discussed this recommendation and then voted that the present Fellow nomination be resubmitted next year as a new nomination without prejudice, since only one opening exists for Fellow membership at this time. Glenn McMullen was recommended as an Honorary Life Member and this action was presented and approved by Council as a ratification of action taken at the November 10, 1985 meeting. It was announced that the Ivey F. Lewis Distinguished Service Award will not be given this year. V. Remsburg also made a special report (attached) concerning the request from Sections that monies collected for Section Awards be run through the VAS treasury to give tax deductible status. The recommendations of the Committee were:

1. That no monetary value be attached to any certificate that may be given up to any section member from any of the sections that would be tax deductible.

2. That approval be given by Council for certificates to be made available from the Academy to all sections wishing to use certificates to identify outstanding research papers or other outstanding activities to members in all sections of the Academy.

a. That the cost of designing and preparing certificates be paid for from the Academy funds.

b. That the Executive Secretary-Treasurer prepare and provide such certificates upon request to Section Chairman of his designated representative.

3. That strong encouragement be given to members of all sections to submit research papers to the Research Committee for the J. Shelton Horsley Research Award.

4. That encouragement be given to members of all sections to submit names of members for the various awards now in existence in the Academy to the Awards Committee.

The Council approved this committee's special report and recommendations with a clarification of item 1 concerning monetary awards.

b. Constitution and By-Laws - It was stated that the duties of this committee need to be written down. President Bass will request such a list. Also Jim Midyette had stated to President Bass that the election of the VJAS Director to the Executive Committee may not be in accordance with the constitution and by-laws. Council also discussed the fact that they felt it would be correct procedure. This will be researched and discussed further.

c. VJAS - The publication of the Proceedings of the annual VJAS meeting has become quite a job. The committee will seek \$7000/yr over a three year period from the Gwathmey Memorial Trust Fund to help meet the increasing cost of this publication. It was stated that Bethel High School has raised a \$10,000 gift for the VJAS for \$1000/yr scholarship. Four students will be sponsored to the VJAS meeting in Philadelphia this year. J. Murray moved that the VJAS Committee be empowered

to convert any cash awards (presently being given) to tangible awards such as plaques with the concurrence of the persons establishing the award, if possible. M. Bass seconded the motion and it passed. M. Bass gave an update on the procedure for selecting college students for the two AAAS honorary memberships offered each year.

d. Nominations and Elections - E. Thompson filed a report for the committee. Nominees for the May meeting are:

President Elect - WILLIAM BANKS & ROBERT DUNCAN

Secretary - MICHAEL BASS & PAUL HOMSHER

Treasurer - ANN PENBERTHY & JAY STIPES

e. Research Committee - A report was filed by W. Banks. The Seed Grant Program funded one proposal for \$500 in October. The Horsley Cancer Research Grants Committee supported three projects at requested levels. The Horsley Research Award will be given to one of five papers now being reviewed by the Florida Academy of Science for the VAS.

f. Trust - D. Ulrich recommended that the Research Committee be authorized to grant \$5000 in 1986 and that the Trust Committee be allowed to transfer \$3000 to the Investment Company of America account to enable maximum growth. D. Decker moved such and J. Murray seconded the motion. The motion was passed.

g. Long Range Planning, Membership, Publications, Science Advisory, Science Education and Virginia Flora - No report.

9. Ad Hoc Committees -

a. Archives - A report was filed by K. Bovard. (attached)

b. News and Publicity - A report was received by mail. (attached)

c. Business Relations, Evolution and Meetings - No reports were given for these committees.

10. Old Business - It was recommended that President Bass write to the Governor suggesting that Vera Remsburg be reappointed to the Board of the Science Museum of Virginia. H. Bell made a motion to that effect and A. Campbell seconded the motion. The motion was passed.

The meeting was adjourned at 4:04 p.m.

ROBERT L. DUNCAN, Secretary

**Virginia Academy of Science  
Executive Committee Meeting  
Minutes: March 15, 1986**

The Committee met in Chandler Hall on the campus of James Madison University in Harrisonburg, VA. The meeting was called to order by President Bass at 10:12 a.m. Present: R. Bass, M. Bass, B. Bruner, D. Decker, R. Duncan, N. Garrison, J. Murray, C. Sellars, B. Silver and G. Trelawny.

It was announced that the speaker for the VJAS and VAS meetings in May will be Dr. Robert Parker, NASA astronaut. Dr. Parker served as mission specialist on STS-9/Spacelab-1 which launched on November 28, 1983 and landed on December 8, 1983. His current assignment is training as a mission specialist for Space Shuttle flight 61-E/ASTRO-1 which was scheduled for launch in March 1986. The publicity information received from NASA (attached) was discussed and it was agreed that this announcement should be made statewide.

An announcement was made that the Vice President of Student Affairs at U of R, Bill Leftwich (brother of immediate VAS Past President Frank Leftwich) had died on March 14, 1986 and the funeral would be in Richmond on Monday, March 17, 1986.

The liability insurance which the VAS was carrying has expired. After a discussion of need for this type of insurance, it was decided that Ertle Thompson (AAAS representative) should inquire about AAAS liability coverage and bring a report at a future date.

Jim Midyette (Constitution and By-Laws Committee) informed President Bass that it may not be correct procedure to elect the VJAS Director to the Executive Committee. This will be decided after some research and further discussion at the May meeting.

President Bass received the approval of the Executive Committee to recommend to the Council that he write a letter to the Governor suggesting Vera Remsburg be appointed for another term on the board of the Science Museum of Virginia.

President Bass stated that he had written to Jim McMullen at Va Tech and welcomed him to honorary membership in the VAS.

A discussion was held on the dues structure and the favorable effect it appears to have had on membership at this point.

President-Elect Jim Murray submitted a report (attached) which he reviewed and stated that he would ask the Council for action on a request by the Biology Section for funding of incidental expenses of a symposium on Vertebrate Life Histories in Virginia to be held at the May VAS meeting. This proposal was thought to be an appropriate response to Dr. Frank Leftwich's call for initiatives from the sections.

Gil Trelawny (Chairperson of the Local Arrangements Committee) introduced Bev Silver, Norm Garrison and Clete Sellars from that committee. They reviewed the arrangements for the May meeting. Deadlines, agenda, publicity and other matters were discussed. The entire program was reviewed.

The minutes from the previous Executive Committee meeting on November 10, 1985 were approved as corrected.

The Executive Committee adjourned at 12:05 p.m.

## Bethel High School Scholarship

James B. O'Brien, Chair  
News and Publicity Committee

As far as can be determined no other fund of its type exists. The Bethel High School Scholarship is unique in that it was entirely endowed by high school students concerned with the importance of science education. Not only did Bethel students achieve their goal of a \$10,000 endowment within a two-year period, but this figure represents a mere fraction of their generosity and charitable commitment. Theirs is a story which merits telling.

Each year, in the twelve days before Christmas vacation; the students of Bethel High School focus on the spirit of giving, and target specific charities and worthy organizations to which they wish to donate. "In one sense, it's quite unremarkable because there is no gimmick," says Jerry Pierpont who coordinates student activities at Bethel. "The students just open their hearts and their pockets to those less fortunate than they are."

Many students give from their allowances. Also, a friendly competition has developed among a number of classes and some launch fund-raising activities at the school. One class, for example, seized the opportunity as a means of learning how to manage a business; and sold popcorn during lunch periods and other breaks in the daily routine at Bethel. They discovered first-hand how to have enough popcorn available in the right place at the right time, how to establish prices, schedule personnel, calculate supplies, market their product, and so forth. The larger lesson for all the students, of course, is one of commitment to helping others. The overwhelming support of this annual event suggests the larger lesson has been well-learned indeed.

In December 1985, Bethel's 1500 students raised an amazing \$10,000. Gifts of \$500 were distributed to the Salvation Army to buy Christmas toys for poor children, the Peninsula Area Home for Battered Women, Hampton Ecumenical Lodging and Provisions, Hampton Social Services' Emergency Food Closet, and the Spina Bifida Foundation. Northampton Rescue Squad and "The Loving Tree" of Hampton General Hospital each received gifts of \$400.

The students appear to hold a special affection for the Ronald McDonald House. With their \$2500 donation, Bethel High School's students constitute the single largest Hampton Roads area donor to this refuge for families with sick children. Among all levels of education institutions, Bethel's students constitute the largest single donor to any of the nation's 85 Ronald McDonald Houses.

The idea of helping a student with a college scholarship was initiated three years ago by Bethel science teachers and the school's chapter of the Virginia Junior Academy of Science. Working with the Academy and chapter sponsor, Don Rima, they developed the scholarship concept as a way of supporting science education and also as a means of actively practicing the kind of social responsibility that scientists must be expected to have.

"The scholarship is kind of a spin-off of the yearly event," according to Principal Tom Bailey. "We're all aware that things like athletics involve a lot of effort and skill; but those achievements can be so easily overemphasized in our society in terms of fame and fortune. The scholarship was a way the students could provide a tangible high-level recognition of intellectual excellence. It was an opportunity for them to say to their peers across the state that the hard work and dedication required for sound learning represent a pursuit which is critical to our nation's future. We felt the Virginia Academy of Science was a worthy body for carrying out these aspirations and making them a reality."

In 1984, Bethel saw its dream becoming a reality with the students contribution of \$4,700 to the scholarship fund. Investment proceeds increased this figure to \$5,800. In December, a check for the \$4,200 balance was



presented at the Annual Christmas Assembly to Academy President, R. Gerald Bass. Also in attendance were R. Dean Decker, Director of the Virginia Junior Academy of Science, and VJAS President Kristen S. Epperly. President Bass noted the significance of the students' endowment of the fund: "What Bethel's students have done is to remind scientists and the nation that science is a way of life. It is intellectual hard work to be sure; but equally important is that the scientist must actively respond to the needs of all the citizens who make up our great country. The two cannot be separated."

The generosity of the students at Bethel High School suggests learning and responsibility are inseparable no matter who we are or which careers we have chosen. Kindness and concern, their example tells us, are part of being human.

The Virginia Academy of Science administers the Fund, and proceeds from investments of the capital constitute the Scholarship Award. Any Virginia high school student evidencing significant scientific interests is eligible for the Scholarship. Determination of the recipient is made by a committee of the Academy at the Annual Meeting based on a combination of the quality of a student's written paper and his or her oral presentation.

The first award of the Bethel High School scholarship will be made at the May meeting by Bethel principal, Thomas E. Bailey and John Murphy and Charlee Anderson, Presidents of the Bethel Student Council Association for 1984 and 1985, respectively.

**The Virginia Social Science Association  
1986 Distinguished Scholar Award in Psychology  
Presented to  
Dr. Raymond H. Kirby  
on behalf of  
The Virginia Social Science Association  
and its  
1986 Psychology Scholar Award Committee**



The Distinguished Scholar Award in Psychology was presented to Dr. Raymond H. Kirby by Dr. Jones P. O'Brien, Chairman of the awards committee, during the annual awards luncheon. The fifty-ninth Annual Meeting of the Virginia Social Science Association at Longwood College, March 21-22, 1986.

The Distinguished Scholar Award in Psychology has been made only once in its six years of existence... in 1982 the Association honored the exemplary work of the late Austin Grigg of the University of Richmond. This year's honoree is equally special, we believe, in the esteem of Virginia psychologists.

He has been chosen unanimously by the Committee. This was not an easy matter because of the outstanding qualifications of so many of this year's nominees. My colleagues on the selection committee, Stuart Smith and Judith Scott, whom I want to warmly thank for their devoted efforts..., they and I thoroughly enjoyed this happy dilemma; and we feel certain that some of these nominees will be honored similarly in the future.

Ray Kirby has taught at Old Dominion University since 1968. Among his nominators were former students who recalled his devotion to professional rigor and high scientific standards combined with a genuine warmth and individual regard. His colleagues note his decisiveness, his ability to grasp the essence of a problem quickly and then act

expediently. He chaired the ODU Psychology Department for two five-year terms and led it to its present status of national acclaim. Dr. Kirby's penchant for diligent work and creativity is obviously reflected in the Faculty with whom he has been so long associated; and it is certainly one of the most productive, academically and scientifically, in Virginia.

Old Dominion University has formally recognized his multiple contributions on three occasions. In 1970 he was accorded the honor of the Delta Phi Omega Award. His distinguished service was noted in 1984 by the Gene W. Hirschfeld Award and again in 1985 by the Rufus Tonelson, Jr. Award.

If Ray is solution-oriented, he is equally an advocate of those values we hold so dear in education and civic service. He fostered educational endeavors at other institutions as well as Old Dominion, and was always ready to assist these other Faculty, to share resources and counsel, as they initiated their programs. In the community Ray is also an advocate, an example of which is his work to bring a fuller life to the handicapped.

Specific examples of Ray Kirby's work and influence on psychology, education, and administration include:

Past Chair of the Old Dominion University Faculty Senate;  
Past Chair of the Psychology Section of the Virginia Academy  
of Science; President-Elect of Tidewater Human Factors  
Society; President of the ODU Chapter of Phi Kappa Phi  
National Honor Society; membership and active leadership in  
the American Psychological Association, the Human Factors  
Society, the Southeastern Psychological Association. He  
served as an officer or on the Board of Directors in all of  
these professional organizations.

An author of over 50 articles, technical reports, and reviews; Ray is currently Director of the Center for Applied Psychological Studies at Old Dominion University.

## Necrology

Dr. William H. Leftwich, vice president for student affairs at the University of Richmond, died March 14, 1986 at his home after a heart attack. He was 54.

He was one of four senior officers reporting to the university's president. He supervised all aspects of student life, from orientation to housing and career services to social activities.

A native of Richmond, Dr. Leftwich earned a bachelor's degree in psychology in 1952 and a master's in sociology in 1956, both from the University of Richmond. He earned a doctorate in psychology in 1962 from Purdue University.

He had been a licensed psychologist for the state and a consultant to business and industry before joining the university's psychology department in 1961.

From 1966 to 1970, he was chairman of the psychology department and was director of the Center for Psychological Services. He also was psychology editor for the Virginia Journal of Science, which is published by the Virginia Academy of Science. From 1968 to 1972, he was associate dean of the university's summer school.

Dr. Leftwich was named a full professor in 1971 and in 1972 became director of student services and activities. He was named vice president a year later.

He was a member of River Road Baptist Church's board of administration, the state and national associations of personnel administrators and of the board of the Charles B. Keesee and the E. R. Patterson educational funds. He also was an advisory board member of the Phi Gamma Delta chapter at the University of Richmond.

He served for a year on the special education advisory council for Henrico County Public Schools and wrote a number of professional articles.

## MEMBERSHIP

Membership in the Academy is organized into sections representing various scientific disciplines as follows:

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|--|-----------------------------------|
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| 4. Biology                             | 12. Statistics                    |
| 5. Chemistry                           | 13. Space Science &<br>Technology |
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**NOTES**

# NOTES

# NOTES



# VIRGINIA ACADEMY OF SCIENCE

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Fujishima, A. and Honda, K. 1972. Electrochemical Photolysis of Water at a Semiconductor Electrode. *Nature* 238: 37-38.

Spry, A. 1969. *Metamorphic Textures*. Pergamon Press, New York. 350 pp.

Guliday, John E. 1971. Pleistocene History of the Appalachian Mammal Fauna. *In* *Distributional History of the Southern Appalachians, Part III. Vertebrates* (Perry C. Holt, ed.). pp. 223-262. VPI & SU, Blacksburg, Va.

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Authors will be allowed 15 printed pages (including figures) free, but payment of \$25 per page will be charged for the 16th and subsequent pages.

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**Abstracts of Papers Presented at the  
Sixty-fourth Annual Meeting, Virginia Academy of Science  
May 13-16, 1986, James Madison University, Harrisonburg, Virginia**

**Aeronautical and Aerospace Sciences**

MODULAR INTERACTIVE ORBITAL MECHANICS PACKAGE FOR USE IN MICROCOMPUTER APPLICATIONS. David A. Barnhart<sup>\*</sup>, Dept. of Aerospace and Ocean Engineering, Va. Polytechnic Institute and State University, Blacksburg, Va. 24061. Classical and modern techniques for solving elementary space mechanics problems are utilized in the microcomputer TURBO Pascal<sup>tm</sup> program, EPOCH. Each problem is broken into separate units for independent interactive use called from a central menu. A pool of system, screen, and I/O operation routines runs each unit, supporting the concept of modularity. Basic orbital mechanics problems such as local sidereal time calculation, ground site inertial coordinate determination, orbiting object inertial coordinate determination, orbital element prediction, Keplers time of flight problem, Lamberts problem, simple orbital transfer calculation, and basic intercept/rendezvous cost calculations are presented. Additional work in detailed space dynamics problems and graphics modeling are possible enhancements for future versions.

STUDIES OF CAVITY FLOWFIELDS AT SUPERSONIC SPEEDS. O. Baysal<sup>\*</sup>, Old Dominion Univ., Norfolk, VA, 23508, R. L. Stallings<sup>\*</sup>, S. Srinivasan<sup>\*</sup>, NASA Langley Res. Ctr., Hampton, VA, 23665. Experimental and computational studies to describe cavity flowfields at supersonic speeds are being conducted. The experimental portion of the work has produced pressure distributions and schlieren photographs of the cavity flowfield. The computational simulation of the flowfield is produced by solving the conservation form Navier-Stokes equations on the generated grid for the particular geometry. Turbulence is modeled and shocks are captured. Flow separation at the cavity forward edge, which initiates the pressure fluctuations and recirculating flow inside the cavity, is shown through the simulated results which are generated using the VPS-32 parallel processor. Depending on the length-to-depth ratio (L/D) the characteristics of the cavity flowfield varies. The shear layer may bridge the "open cavity," however, it deflects inwards in the case of the "closed cavity." Therefore, the former creates smaller local turning angles and poses more favorable flowfield features. A sudden jump in the drag coefficient is experienced around a certain L/D (critical L/D). A hysteresis effect is observed in obtaining the critical values of L/D that depended upon whether the flowfield switched from open cavity to closed cavity or vice-versa.

OPTIMAL EVASION WITH A PATH-ANGLE CONSTRAINT. J. Ben-Asher<sup>\*</sup>, Dept. of Aerospace and Ocean Engineering, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. We consider the problem of optimal evasion when the pursuer is known to employ proportional navigation. The performance index is a measure of closest-approach, and we include a constraint on the evader's terminal path-angle. This constraint is important if, for example, the evader is attacking a fixed-target. The analysis is done for planer motions and allows unbounded maneuverability for the pursuer. The dynamics are first linearized around a nominal collision course, and the resulting optimal control problem is solved analytically. The optimal controls are bang-bang; with the number of switches depending on the pursuer's navigation gain. For some cases the optimal strategy can be decomposed into a maneuver used to satisfy the terminal constraint followed by the unconstrained evasive maneuver.

**CONTINUOUS FLOW OF AN INCOMPRESSIBLE FLUID IN A PARTIALLY FILLED, RAPIDLY ROTATING CYLINDER WITH A DIFFERENTIALLY ROTATING ENDCAP.** Jeffrey W. Frederick, Dept. of Chem. Eng., and Robert J. Ribando, Dept. of Mech. Eng., Univ. of Va., Charlottesville, Va. 22901. Axial countercurrent flow in a centrifuge with and without continuous feed addition and removal was studied experimentally and numerically. The equations of motion were solved using a finite difference formulation with analytic matching conditions at the top and bottom boundary layers. A laser-Doppler velocimeter was used to measure axial and azimuthal velocity components. The results of the numerical simulations were in good agreement with the experimental measurements. For no feed the countercurrent drive was strong near the differentially rotating endcap and decayed axially over the length of the cylinder. For continuous feed alone the flow was confined mainly to the inner free surface and top and bottom boundary layers. For feed addition and a differentially rotating endcap axial countercurrent flow increased in the region between the feed point and the differentially rotating endcap and decreased in the region between the feed point and the other end of the cylinder.

**COMPUTERS FOR CONCEPTUAL AIRCRAFT DESIGN.** Vicki S. Johnson, NASA Langley Research Center, Hampton, VA 23665. The goal of the conceptual design process is to transform a given set of mission requirements into a potential configuration that will meet those requirements. Application of the computer to conceptual design has traditionally been more of an art than a science. The aircraft designer still must develop the ideas, conduct the design, and make the decisions. However, the computer can provide a great deal of flexibility to the designer, particularly in geometry generation and manipulation for aircraft configurations. A computer code for the geometry development and initial analysis of aircraft concepts will be described along with how this code relates to the complete conceptual design process. A discussion of the benefits and limitations of the code will be interspersed with illustrations of unique aircraft concepts developed using the code.

**SENSITIVITY ANALYSIS OF LARGE SPACE STRUCTURES USING A REDUCED MODAL MODEL.** Chris A. Sandridge\* and Raphael T. Haftka\*, Dept. of Aerospace and Ocean Engineering, Va. Tech, Blacksburg, Va. 24061. Vibration suppression in large space structures requires the use of active control systems which are typically designed using a reduced structural model based on a small number of vibration modes. The number of modes selected for the reduced model is based on the requirement of accurate prediction of the control system performance. Recently, there is interest in making small structural changes to improve the control system performance. Thus, the sensitivity of the control system performance to changes in structural parameters is needed. It is shown that with a reduced model, the accuracy of these sensitivities can be substantially poorer than the accuracy of the control system performance. In particular, large errors in these sensitivities occur when the modes of the structure are closely spaced. (Supported by NASA contract #NAG-1-603.)

**SOME FACTORS THAT HAVE INFLUENCED U.S. AIRCRAFT DEVELOPMENTS.**

M. Leroy Spearman, NASA Langley Research Center, Hampton, VA 23665. This paper will provide a historical review of the major factors that have had a pronounced effect on the progressive development of aircraft, particularly in the United States. The areas of technology to be included are primarily aerodynamics, propulsion, structures and materials, and avionics. Other factors that will be considered include test techniques (ground and flight); mission requirements; political environment; economic environment, and so on. The review will indicate that significant technological progress is reflected in aircraft development although, at times, technological progress has been tempered by nontechnical issues.



## Agricultural Sciences

DISEASES OF SELECTED WEEDS IN VIRGINIA. A.B.A.M. Baudoin, Dept. of Plant Pathology, Physiology, and Weed Science, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. A survey of pathogens of selected weeds in Virginia was conducted between August 1983 and October 1985. Collections were made in 40 counties in all areas of Virginia. Pathogens were isolated and cultured, and pathogenicity of many was confirmed by inoculation of healthy plants. Pathogens of 16 weeds were collected, with most of the effort spent on kudzu, milkweed, poison ivy, hemp dogbane, and johnsongrass. A preliminary assessment of the potential of these pathogens for use as biological control agents for the target weeds indicated that most were not promising candidates. A preliminary field test of applications of Colletotrichum fusarioides to milkweed did not result in effective milkweed control. The frequency of occurrence and the distribution of the pathogens collected will be discussed. Several pathogens have apparently not previously been reported on the weed host involved, including: Aphelenchoides sp. on milkweed, Phomopsis sp. on hemp dogbane, and Phyllosticta sp. on kudzu. Many others have not been reported previously in Virginia, including Dichotomophthora indica on purslane. (Supported in part by the Virginia Highways & Transportation Research Council)

THE EFFECT OF SUPPLEMENTAL VITAMIN E ON HUMORAL IMMUNE RESPONSE OF PIGS WEANED AT VARIOUS AGES. E.D. Bonnette\*, E.T. Kornegay, Dept. of Anim. Sci., C. Hammerberg, Dept. of Patho. Biol. & D.J. Blodgett\*, Dept. of Vet. Bio. Sci., Va. Polytechnic Inst., Blacksburg, Va. 24061. A 2 x 3 factorial experiment was used to measure the effects of supplemental vitamin E and weaning ages on serum vitamin E, cortisol, total antibody and IgG levels. Six pigs within each litter were paired by weight and each pair was randomly assigned to one of three weaning ages, 21, 28, 35 d. One pig from each pair was fed a 20% crude protein diet with NRC recommended vitamin E (11 IU/kg) and the other pig was fed the same diet supplied with 20 x NRC vitamin E (220 IU/kg). Pigs were injected IM at weaning and again 14 d later with sheep red blood cells (SRBC) in Freund's incomplete adjuvant. Serum was taken weekly and frozen until analyzed. Vitamin E was analyzed colorimetrically. The cortisol was measured with a radioimmunoassay. A passive hemagglutination test was used to obtain total antibody and IgG (serum was treated with mercaptoethanol) titers. Body weight gain was not affected by dietary vitamin E level and increased as weaning age increased. There was an increase ( $P < .01$ ) in plasma vitamin E levels in the 20 x NRC diet compared with NRC controls. There was also a decrease in cortisol levels as vitamin E levels in the diet increased. Various weaning ages or dietary vitamin E levels did not affect total antibody or IgG production. In summary, increasing the level of dietary vitamin E to 20 x NRC increased vitamin E concentration in blood and decreased cortisol levels compared with the controls but neither treatment had any effect on humoral immune response.

THERMAL INACTIVATION OF SCLEROTIA OF SCLEROTINIA MINOR. T. B. Brenneman, P. M. Phipps, and R. J. Stipes, Department of Plant Pathology, Physiology, and Weed Science, VPI & SU, Blacksburg, VA 24061.

The thermal inactivation of Sclerotinia minor sclerotia was investigated, considering the influence of culture media, isolate differences, and age of sclerotia. These studies utilized a 10 min treatment at 41, 43, 45, and 47 C. Sclerotia produced on autoclaved oats were more heat resistant than those from glucose yeast-extract agar (GYEA) which were rendered nonviable at 47 C. Differences were also found among isolates of the fungus. A field isolate of S. minor germinated faster at lower temperatures, but was more susceptible to 47 C than were two fungicide-resistant strains. The ability of sclerotia to withstand heat stress was found to increase as they matured. Younger sclerotia were killed at 47 C, but after 6.5 and 7.5 wk the survival rate was 75% and 100%, respectively. Time of exposure to heat was also a significant factor; a 12-hr exposure to 39 C was lethal to sclerotia produced on GYEA, and both 37 C and 35 C greatly delayed their germination. High temperatures may be responsible for death of some sclerotia in tidewater Virginia where soil temperatures greater than 40 C have been recorded at a depth of 2 in.

A PILOT EXPERIMENT OF THE EFFECTS OF PLANT GROWTH REGULATORS ON THE DEVELOPMENT OF AZALEA LACE BUGS. M. A. Coffelt and P. B. Schultz, Dept. of Entomol., VPI & SU, Va. Trk and Ornam. Res. Stn., Virginia Beach, VA 23455. The plant growth regulators dikegulac sodium (Atrinal), chlormequat chloride (Cycocel), diethanolamine salt of mefluidide (Embark), and methyl octonate and decanoate (Off-Shoot-O) were evaluated for their influence on development of azalea lace bug, Stephanitis pyrioides Scott. Foliar sprays were applied to Rhododendron sp. 'Tradition' and development was evaluated 11, 19, and 22 days post-treatment. Off-Shoot-O, Atrinal, and Embark significantly slowed development after 11 days; conversely, these same substances accelerated development after 19 and 22 days. These inhibitory and stimulatory effects were believed to be related to the nutritional quality of the azaleas. Cycocel did not significantly affect S. pyrioides development.

SPECTROPHOTOMETRIC DETECTION OF AIR SAC-COMPLEX IN BLOOD PLASMA PROTEINS OF CHICKENS. Germille Colmano, W.B. Gross,\* C.T. Larsen,\* and A.T. Tischler,\* VA-MD Regional College of Veterinary Medicine, VPI & SU, Blacksburg, VA 24061. After recording the spectrophotometric absorbance of three pools of amino acids in proteins of blood plasma, used as indicators marking differences that established a baseline for normal healthy chickens, we separated high and low antibody lines of 7 week old birds of mixed sex. The analysis of blood, collected immediately before E. coli injection, separated the birds with heart lesions from those with only air sac lesions. In two field trials of 49 day-old birds from two commercial breeders we separated the high from the low air sac condemnation group. In three groups: socialized (gently handled by human contact), unsocialized (ignored, without social contact with humans), and unsocialized stressed by fasting, we separated the socialized from the unsocialized and the socialized from the fast stressed birds. (Supported by a Southeastern Poultry and Egg Association Grant)

RESPONSE OF DIRECT-SEEDED BROCCOLI TO TRIFLURALIN, DCPA AND NAPROPAMIDE. Jeffrey F. Derr, Dept. of Plant Path., Physiol. and Weed Sci., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. Broccoli production has received increased attention in southside Virginia. Herbicide use is limited due to the direct-seeding of the crop, as opposed to field transplanting. A study was conducted to determine the safety and effectiveness of the three registered herbicides for broccoli production. The herbicide rates applied per acre were: trifluralin at 0.5 and 0.75 lbs, DCPA at 6.0 and 10.0 lbs and napropamide at 1.0 and 2.0 pounds. The low rate of each herbicide was evaluated in two-way combinations. All treatments except the low rate of trifluralin provided over 80% control of carpetweed. All treatments except the low rate of DCPA provided over 95% control of pigweed. The high rate of napropamide caused significant reduction in broccoli stand, while DCPA and trifluralin had no effect on crop stand. One month after application, significant crop damage was observed at both napropamide rates and at the napropamide plus DCPA treatment. Crop damage decreased over time. No other treatments caused injury.

EVALUATION OF EXPERIMENTAL POSTEMERGENCE HERBICIDES IN TOMATO. Jeffrey F. Derr, Dept. of Plant Path., Physiol. and Weed Sci., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. The development of postemergence herbicides allows for decision-making in chemical applications, as opposed to preventative applications of preemergence herbicides. Experimental herbicides such as fluazifop, sethoxydim and DPX-Y6202 selectively remove emerged grasses from broadleaf crops such as tomato. Research is needed to determine if these compounds can be tank-mixed with the broadleaf herbicide metribuzin for broad-spectrum annual weed control in tomato. The grass herbicides fluazifop (0.125, 0.156 and 0.188 lb/A), sethoxydim (0.20 lb/A) and DPX-Y6202 (0.06 lb/A) were applied separately or in combination with 0.25 lb/A metribuzin. When applied separately, each of the grass herbicides provided essentially 100% control of giant foxtail, with no control of common lambsquarters. Metribuzin provided complete lambsquarters control, but no control of giant foxtail. The combination of metribuzin with any of the postemergence grass herbicides provided over 90% control of both species. None of the treatments caused injury to tomatoes. The development of these experimental compounds would allow selective control of many emerged weeds in tomato, especially when mixed with presently recommended herbicides.

PHYTOTOXICITY OF INFUSED HERBICIDES TO TREATED AND ADJACENT PIN OAKS (QUERCUS PALUSTRIS). Jeffrey F. Derr and R. Jay Stipes. Dept. of Plant Path., Physiol., and Weed Sci., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061. A study was conducted to determine if herbicides injected into trees could be translocated in phytotoxic amounts to adjacent trees through root grafts. The herbicides glyphosate, dicamba and tebuthiuron were infused into six-inch diameter pin oaks in August, 1985. The rate of each herbicide applied in 1 l of water per tree was: 8 ml of a 4 lb/gal glyphosate formulation, 8 ml of a 4 lb/gal dicamba formulation and 19 g of a 20% tebuthiuron formulation. The glyphosate and dicamba solutions were rapidly absorbed while the tebuthiuron solution was not completely absorbed. One month after application, the dicamba and glyphosate treated trees were dead while the tebuthiuron treated tree showed no injury symptoms until later in the year. None of the trees adjacent to the glyphosate and tebuthiuron infused trees exhibited injury symptoms. One tree adjacent to the dicamba treated tree showed herbicide damage. Preliminary results suggest that herbicide exudation through roots, followed by root absorption, may be more important than herbicide translocation through root grafts of adjacent trees.

PREMATURE OOTHECAL DROP AND SUBSEQUENT HATCH IN THE GERMAN COCKROACH, Blattella germanica, (DICTYOPTERA: BLATTELLIDAE) (L.) IN RESPONSE TO PROPOXUR. James D. Harmon\*, & M. H. Ross, Dept. of Entomology, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. The behavior of adult female German cockroach in response to insecticides includes the premature dropping of the ootheca. Adult females carrying their first egg case were exposed to filter paper impregnated with a set dosage of propoxur for a standardized time period. Premature oothecal drop and subsequent mortality of females, percentage hatch, time to hatch and immediate nymphal survival from oothecae dropped on the treated surface were observed. Mortality of females that dropped oothecae prematurely was higher than that of females that retained their oothecae in both an insecticide resistant and a susceptible strain. Oothecae drop by resistant females was significantly less than that by susceptible females. Oothecae hatching on a treated surface produced a significant reduction in time to hatching, percentage hatch and percentage nymphal survival. This indicates that the behavior trait of holding onto the oothecae when exposed to an insecticide treated surface is advantageous to the cockroach. It may be a type of adaptive strategy not reported here to fore. It was also apparent that this behavior is highly variable within a population.

COMPARATIVE EFFECTS OF OXADIAZON AND ITS METABOLITES ON LIPID SYNTHESIS OF SOYBEAN LEAF CELLS. Kriton K. Hatzios, Dept. of Plant Path., Physiol. & Weed Sci., VPI & SU, Blacksburg, VA 24061. The effects of the herbicide oxadiazon [2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- $\Delta^2$ -1,3,4-oxadiazolin-5-one] and four of its major plant metabolites designated as OXA-1 (mono-dealkylated oxadiazon), OXA-2 (di-dealkylated oxadiazon), OXA-3 (alcohol derivative of oxadiazon), and OXA-4 (carboxylic acid derivative of oxadiazon) on the incorporation of  $^{14}\text{C}$ -acetate into enzymatically isolated leaf mesophyll cells of soybean [Glycine max (L.) Merr., cv. Essex] were evaluated. Cells suspensions containing 40-50  $\mu\text{g}$  of chlorophyll were treated with oxadiazon and the four metabolites at 0, 0.1, 1, 10, and 100  $\mu\text{M}$  in the presence of 1  $\mu\text{Ci}$  of  $^{14}\text{C}$ -acetate. Time-course studies included incubations of 30, 60, and 120 min. Oxadiazon and its four metabolites were not strong inhibitors of lipid synthesis. Appreciable inhibition was observed only with the highest concentrations (10 and 100  $\mu\text{M}$ ) of oxadiazon, OXA-1, OXA-2, and OXA-4. The respective inhibition percentages were 68, 66, 85, and 90% at 30 min. The dependence of these effects on incubation time was minimal. OXA-3 was totally inactive as an inhibitor of the incorporation of  $^{14}\text{C}$ -acetate into lipids of isolated soybean leaf cells.

INFLUENCE OF MOISTURE, NUTRIENTS, AND STRIGOL ANALOGUES ON GERMINATION OF BROOMRAPE SEEDS. R. Jain and C. L. Foy, Dept. of Plant Pathol., Physiol. and Weed Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061. Broomrape (Orobancha spp.) is a phanerogamic holoparasite that subsists on the roots of many economically important plants. The seeds of broomrape do not germinate readily but require a period of preconditioning under suitable moisture and temperature followed by a chemical stimulus from host root exudates before germination. Two strigol analogues, GR 7 and GR 24, were found to stimulate the germination of preconditioned O. aegyptiaca, O. ramosa, and O. crenata seeds in the absence of host root exudates. O. ramosa seeds were most sensitive to germination stimulation by the strigol analogues, followed by O. aegyptiaca and O. crenata seeds. O. aegyptiaca seeds preconditioned in various nutrient solutions showed higher germination in the presence of nitrogen than in the presence of potassium and phosphorus alone and in combination with nitrogen. Nitrate salts were more effective than ammonium salts in stimulating germination of O. aegyptiaca seeds. Moisture stress during preconditioning also inhibited broomrape seed germination.

EVALUATION OF AGRICULTURAL BEST MANAGEMENT PRACTICES USING A RAINFALL SIMULATOR. A. L. Kenimer\*, S. Mostaghimi\*, and T. A. Dillaha\*, Dept. of Ag. Engr., VPI & SU, Blacksburg, Va. 24061. Agricultural Best Management Practices (BMPs) have become accepted methods for reducing soil, water, and nutrient losses from agricultural lands. However, many of these practices have not been adequately evaluated because natural precipitation is highly unreliable when field research is being conducted. As a remedy for this situation, a rainfall simulator was designed and constructed for the assessment of agricultural BMPs. Since its existence, the rainfall simulator has been used for a number of studies which investigated the effects of BMPs on the quality of runoff from agricultural lands. The BMPs examined, the methods of evaluation, and the results are presented.

INTERACTIVE EFFECTS FOR SUPPLEMENTAL BIOTIN AND COPPER FOR WEANLING PIGS. E.T. Kornegay, M.D. Lindemann, Dept. of Anim. Sci., D.J. Blodgett\*, Dept. of Vet. Bio. Sci. & G.G. Schurig, Dept. of Patho. Biol., Va. Polytechnic Inst., Blacksburg, Va. 24061. A five-week weanling trial was conducted using 96 crossbred pigs (6.9 kg initially) to determine the influence of supplemental biotin levels (0, 220, 440, and 880 ppb) and copper levels (0, 200 and 400 ppm) on growth rate, serum and liver Cu levels, hemoglobin concentrations, and immune response (humoral and cell-mediated). Blood samples were taken initially and on d 25 and 35 for determination of serum Cu, hemoglobin and antibody titers. In general, 200 ppm Cu improved growth rate while 400 ppm reduced growth during the 4th and 5th wk. Serum and liver Cu levels were elevated and hemoglobins were depressed, indicating that 400 ppm Cu was toxic. Growth rate was greatest for pigs fed 440 ppb biotin. High levels of Cu depressed the response to phytohemagglutinin (PHA) and sheep red blood cells (SRBC), but had no effect on the response to lysozyme. Interactive effects of Cu and biotin are suggested by significant interactions in which the two highest levels of biotin seemed to enhance the pig's response to PHA and lysozyme at high levels of Cu, but depressed the response at the low Cu level. It was also noted that the immune response of males to SRBC and lysozyme was generally depressed with added biotin, but the response of females was enhanced. With the exception of these somewhat unexplained interactive effects of dietary Cu and biotin levels on the immune response, there appeared to be no interactive effects of added biotin and added Cu for weanling pigs with an improvement in growth rate when 200 ppm Cu or 440 ppb biotin was added to the diet.

INFLUENCE OF COMMERCIAL CABBAGE PEST MANAGEMENT ON THE IMPORTED CABBAGEWORM AND IT'S MAJOR PARASITE, PTEROMALUS PUPARUM, IN SOUTHWEST VIRGINIA. J. A. Lasota and L. T. Kok, Dept. of Entomol., VPI&SU, Blacksburg, Va. 24061. Prophylactic application of chemical insecticides for control of the imported cabbageworm, cabbage looper, and diamondback moth, and plowing fields in the spring or after harvest in the fall, are important pest management practices of cabbage production in southwest Virginia. The influence of these practices on populations of Pteromalus puparum (L.), a major gregarious pupal parasite of the imported cabbageworm, was investigated. Residual effects of methomyl, permethrin, and fenvalarate were tested in the laboratory on adult P. puparum. Survival of adult female parasites did not differ from that of untreated controls. Higher male mortality was found following exposure to methomyl for 12 h and for 6 days than in the controls. Imported cabbageworm larval populations on residual cabbage growth late in the growing season moved out of cabbage fields in search of overwintering pupation sites. Greater than 60% of these overwintering pupae were parasitized by P. puparum. Plowing post-harvest cabbage fields at different times may be used to reduce the buildup of imported cabbageworms without suppressing P. puparum populations.

IMPORTED CABBAGEWORM, ARTOGEIA RAPAE (L.), (LEPIDOPTERA: PIERIDAE) CONTROL ON CABBAGE AND BROCCOLI WITH DIMILIN 25 WP. J. A. Lasota, J. E. Roberts, Sr. and M. A. Saluta, Dept. of Entomol., VPI&SU, Blacksburg, VA 24061. Dimilin (diflubenzuron), a chitin synthesis inhibitor, was tested for control of lepidopterous pests on broccoli and cabbage. Feeding damage to cabbage heads and leaves did not differ significantly ( $\alpha=0.05$ ) with 0.5 versus 1.0 lb Dimilin 25WP, although less head and leaf damage occurred on the treated versus control plants. More imported cabbageworm larvae were found on untreated than treated plants, with no significant differences between treatments. On broccoli there was more leaf defoliation on untreated versus treated plants. Differences in leaf damage were not found between treatments of 0.5 and 1.0 lb of Dimilin 25WP. Fewer imported cabbageworm larvae were found on broccoli leaves treated with 1.0 lb. Dimilin than 0.5 lb or control. Broccoli had fewer imported cabbageworm larvae in the heads of plants with both Dimilin treatments than the control plants.

FEEDING VALUE OF RICE BRAN FOR FINISHING PIGS AS AFFECTED BY ANTIOXIDANT INCLUSION DURING STORAGE. M. D. Lindemann and E. T. Kornegay, Dept. of Animal Science, VPI&SU, Blacksburg, VA 24061. The feeding value of freshly milled rice bran and rice bran stored with or without the antioxidant ethoxyquin was evaluated in two feeding trials, each with 72 finishing pigs weighing about 58 kg. Additions of 35 and 70% rice bran to a corn-soybean meal basal diet resulted in linear depressions in daily gain ( $P < .01$ ) and daily feed ( $P < .01$ ) and linear increases in feed:gain ratio ( $P < .01$ ) in both trials whether or not the rice bran and/or diets into which it was incorporated contained the antioxidant. The antioxidant prevented the furtherance of oxidative rancidity in the rice bran stored for one year; however, this did not improve the feeding value of the rice bran. The addition of the antioxidant to the complete mixed diets did increase voluntary feed intake ( $P < .03$ ) and growth rate ( $P < .06$ ) in the later portion of the finishing trial.

INFLUENCE OF A QUARTER CENTURY OF PERFORMANCE TESTING ON ANGUS AND HEREFORD POPULATIONS IN VIRGINIA. T. J. Marlowe, K. Nadarajah and D. R. Notter, Dept. of An. Sci., VA Polytechnic Inst., Blacksburg, VA 24061. Phenotypic, environmental and genetic changes in 13 Angus (A) and 11 Hereford (H) herds following 20 to 30 yr of performance testing were estimated by two procedures: 1) series of regression procedures [ $\Delta D = h^2 \cdot \hat{\beta}(P - \bar{P}_{cont}) \cdot WNYR/herd, sire$ ] and 2) Harvey's (1982) maximum likelihood (ML) mixed model to obtain constants for fixed effects and polynomial regression coefficients for estimating trends in weaning weight (WWT), weaning weight ratio (WWR) and deviation (DEVN) from contemporary group means. There were 27,774 A and 14,738 H progeny from 1,061 sires and 7,732 A dams and 512 sires and 4,304 H dams with an average of 29 progeny/sire. WWT increased approximately 30 kg in both breeds. Sire and dam trends were both positive in most herds but evidence indicated more emphasis on sire selection. WWR and DEVN estimates followed the pattern of WWT. Pooled estimates over herds were 1.0 and .88 kg/yr for A and H, respectively, by the first procedure and 1.22 and .75 by the ML procedure.

INSECTS ASSOCIATED WITH 1985 FALL BROCCOLI IN MONTGOMERY AND HALIFAX COUNTIES, VIRGINIA. T. J. McAvoy\* and L. T. Kok, Dept. of Entomol., VPI&SU, Blacksburg, Va. 24061. Insect fauna of fall broccoli was determined by weekly sampling in a commercial broccoli field in Halifax Co. and an experimental plot in Montgomery Co. In Halifax Co., in decreasing order of abundance the following insects found on broccoli var. 'Southern Comet' (0.06 ha plot) were: green peach aphid (Myzus persicae (Sulzer)), cabbage looper (Trichoplusia ni (Hubner)), corn earworm (Heliothis zea (Boddie)), cabbage webworm (Hellula rogatalis (Hulst)), fall army worm (Spodoptera frugiperda (J. E. Smith)), imported cabbageworm (Artogeia rapae (L.)), green cloverworm (Plathypena scabra (Fab.)), potato flea beetle (Epitrix cucumeris (Harris)), and European cornborer (Ostrinia nubilalis (Hubner)). Beneficials recorded were: Chrysopa oculata Say, Hippodamia convergens Guerin-Meneville, Hyposoter exiquae (Viereck), Cotesia glomeratus (L.), Litomastix truncatellum (Dalman), Pteromalus puparum (L.), a tachnid sp. and syrphid sp. In Montgomery Co., insects found on broccoli var. 'Premium Crop' (0.02 ha) were: M. persicae, A. rapae, cross striped cabbageworm (Evergestis rimosalis (Guenee)), T. ni, E. cucumeris, cabbage aphid (Brevicoryne brassicae (L.)), yellow woollybear (Spilosoma virginica (Fab.)), and H. zea. Beneficials were: C. glomeratus, P. puparum and syrphid larvae.

GENETIC IMPROVEMENT OF PEANUT CULTIVARS RELEASED BY THE VIRGINIA-ARS BREEDING PROGRAM. R. W. Mazingo, Tidewater Res. Ctr., VPI&SU and T. A. Coffelt, USDA-ARS, Suffolk, VA 23437. Peanut (*Arachis hypogaea* L.) yields in Virginia increased from an average of 1120 kg/ha in the 1940's to over 3360 kg/ha in the 1980's. Since many new production practices have been developed during this time period, a three-year study (1982-84) was conducted to measure the improvement in peanut cultivars released by the Virginia-ARS Breeding Program since the mid 1950's. Yield and value increases of an average of 17.6 kg/ha/yr and 12.9 \$/ha/yr, respectively, can be attributed to improvement in cultivars developed by this breeding program. During the 1970's, breeding emphasis was placed on pest resistance and quality acceptance. Consequently, cultivars released to date during the 1980's have not surpassed the highest yielding cultivar developed during the 1970's. Genetic improvement of the highest yielding cultivar (VA 72R) developed by the Virginia-ARS Breeding Program accounted for a 15.7% yield increase and 16.8% value increase over the standard cultivar (VA Bunch 46-2) released in the early 1950's.

#### FOREST CLASSIFICATION OF SOUTHERN APPALACHIAN SPRUCE-FIR ECOSYSTEMS.

N. S. Nicholas\*, S. M. Zedaker\*, Dept. of For., Va. Polytech. Inst. & State Univ., Blacksburg, Va. 24061, C. C. Eagar\*, Sci. Div., Great Smoky Mtn. Nat. Park, Gatlinburg, Tn. 37738, P. S. White\*, Dept. of For., Fish., & Wildlife & Coop. Park Stud. Unit, Univ. of Tn., Knoxville, Tn. 37901. Some stands of the southern Appalachian spruce-fir ecosystem have been observed to be exhibiting some symptoms of decline. Our project is designed to determine the relationships between site and stand characteristics, and the degree of decline and regeneration success of the spruce-fir type. Permanent plots have been established on three geographically distinct areas: Mt. Rogers National Recreation Area (Virginia), the Black Mountains of North Carolina (from Clingman's Peak to Celo Knob), and the Great Smoky Mountains National Park (Tennessee and North Carolina). At each study area, stratification variables include: elevation (four classes ranging from 5000 to 6500 ft), exposure to wind, and slope position (ridge/slope/draw) with three replicates per stratification combination.

Forest classification results are presented using the TWINSPLAN hierarchical classification program. The precision of derived forest type groupings is examined by indirect ordination analysis.

COMMON CATTLE GRUB, *HYPODERMA LINEATUM* (VILLERS), AND NORTHERN CATTLE GRUB, *HYPODERMA BOVIS* (L.) (DIPTERA: HYPODERMATIDAE) CONTROL ON BEEF CATTLE WITH AMERICAN CYANAMID LEVAMISOLE/FAMPHUR ORAL PASTE. J. E. Roberts, Sr. and M. A. Saluta\*, Dept. of Entomology, VPI&SU, Blacksburg, VA 24061. Treatments were administered orally to yearling beef steers in Montgomery County, VA during Sept. of 1984. The treatments were: A) (wormer plus no insecticide) 8mg levamisole plus 0 mg famphur per kg body wt. B) 8 mg levamisole plus 10 mg famphur per kg body wt. C) 8 mg levamisole plus 20 mg famphur per kg body wt. D) 8 mg levamisole plus 30 mg famphur per kg body wt. E) (standard treatment) 8 mg levamisole plus 40 mg famphur (topical) per kg body wt. The number of animals per treatment group ranged from 13 to 19. Treatment efficacy data was collected during Feb. and Mar. of 1985 by palpating along the backline ca. 8 inches on each side of the topline. The percentage of animals infested in treatment A (wormer plus no insecticide) was 73.3% compared with 7.7% in B, 36.8% in C, 25.0% in D, and 10.5% in E (standard treatment). The analysis of the log (n+1) composite data indicated a significantly greater grub infestation in the control group ( $P < .05$ ).

LONGNOSED LOUSE, LINOGNATHUS VITULI (L.) (ANOPIURA: LINOGNATHIDAE), LITTLE BLUE LOUSE, SOLENOPTES CAPILLATUS (ENDERLEIN) (ANOPIURA: HAEMATOPINIDAE), AND BITING LOUSE, BOVICOLA BOVIS (L.) (MALLOPHAGA: TRICHODECTIDAE) CONTROL ON DAIRY CATTLE WITH AMERICAN CYANAMID LEVAMISOLE/FAMPHUR ORAL PASTE. J. E. Roberts, Sr. and M. A. Saluta\*, Dept. of Entomology, VPI&SU, Blacksburg, VA 24061. Experimental treatments were administered orally to yearling dairy cattle in Montgomery Co., VA during Feb. of 1985. The treatments were: A) (wormer and no insecticide), 8 mg levamisole plus 0 mg famphur per kg body wt. B) 8 mg levamisole plus 20 mg famphur per kg body wt. C) 8 mg levamisole plus 30 mg famphur per kg body wt. Six animals from each group were used for evaluation. Treatment groups were maintained in separate pastures to eliminate transfer of lice. Test animals were observed 0, 3, 7, 14, 28, 42, and 56 days post-treatment. The famphur treatments resulted in 100% control of all species of lice 7 days after treatment. A slight reinfestation was observed on all treatment groups on days 28, 42, and 56. Group A (wormer plus no insecticide) maintained moderate infestations of lice throughout the trial period.

HOG LOUSE, HAEMATOPINUS SUIS (L.) (ANOPIURA: HAEMATOPINIDAE), CONTROL ON SWINE WITH GUARDIAN 10% EAR TAGS. J. E. Roberts, Sr. and M. A. Saluta\* Dept. of Entomology, VPI&SU, Blacksburg VA 24061. Guardian® 10% swine ear tags were evaluated for hog lice control when applied to brood sows and gilts in Page Co., VA. The treatments were: A) Untreated control. B) Guardian® 10% ear tags, attached to the inside of the ears (one per ear). C) Guardian® 10% ear tags, attached to the outside of the ears (one per ear). Six animal from each group were used for evaluation. Each group was confined separately in pens in a breeding and gestation barn. Post treatment observations were conducted on weeks 1, 2, 3, 5, 7, 9, 12, 14, and 16. Infestations were determined by quantifying the number of lice found on one side of each test animal, and multiplying the total by 2. The Guardian® 10% swine ear tags resulted in effective control of hog lice for 16 weeks post-treatment. Natural interaction and contact between treated animals within groups was probably beneficial in transmitting the insecticide from the tags to the hair coat.

COMPARATIVE SUSCEPTIBILITY OF CHRYSANTHEMUM VARIETIES TO THE EUROPEAN CORN BORER. P. B. Schultz and M. A. Coffelt, Dept. of Entomol., VPI & SU, Va. Trk and Ornam. Res. Stn., Virginia. Beach, VA 23455. Five screening methods were evaluated to determine if resistance to the European corn borer, Ostrinia nubilalis (Hubner), exists between chrysanthemum varieties. Field studies showed significant differences; the varieties Debonair and West Point were the most heavily infested, with the varieties Grenadine, Patriot, Baby Tears, and Revere showing no infestation. In laboratory studies, Debonair and West Point were again the most heavily infested while Pancho and Revere were the least infested. A direct relationship between infestation levels and stem diameters indicated stem thickness may be a factor in expression of resistance. (Supported by a research grant from the Virginia Nurserymens Association).



CATABOLIC SUBSTRATE DETERMINATION IN THE AMERICAN COCKROACH Periplaneta americana (L.). Peter C. Sherertz, Dept. of Entomology, VPI & SU, Blacksburg, VA 24061. Adult, male American cockroaches were subjected to varying dietary regimens (dog chow and water ad libitum, water ad libitum, dog chow ad libitum and no dog chow nor water) and two levels of humidity, low and medium. Food and water consumption, changes in weight and respiratory quotient (RQ) were determined and compared for the different experimental groups. Insects in both humidity levels exhibited apparent catabolic substrate shifts from typical carbohydrate-based to lipid-based substrates when given water ad libitum and no food. Insects allowed no food nor water apparently do not exhibit this shift, but seem to rely more heavily on carbohydrate-based substrates. Radiolabelled carbohydrate and lipid substrates are being tested under similar dietary and environmental conditions. Carbon dioxide ratios will be compared to determine catabolic substrate utilization patterns under specific dietary and environmental conditions imposed.

FACTORS RELATED TO SOUTHERN CORN ROOTWORM BEETLE TRAPPING WITH PHEROMONES IN PEANUTS. J. C. Smith, Tidewater Res. Ctr. & J. L. Steele\*, USDA-ARS, Suffolk, Va. 23437. A pheromone specific for attracting adult male beetles of the southern corn rootworm (Diabrotica undecimpunctata howardi Barber) was used in sticky-traps from mid-July to mid-September in order to assess potential injury in peanut fruit by the larvae of the insect. Six sites in four counties were utilized to evaluate the potential of the traps in surveying for beetles. Four traps were placed in each site in a rectangular configuration of ca. 1/2 acre each. Bordering crops to the sites included soybeans, corn, cotton, peanuts and mixed hardwoods. Trapped beetles were counted daily at 2 Suffolk sites and twice weekly at another Suffolk site and in Sussex and Greensville counties. Trapping success varied greatly between sites and between traps at each site. Bordering crops appeared to have less effect on trapping success than did within-site location of the trap. At four sites, traps located within the peanut field (i.e. bordered by peanuts on 4 sides) trapped more beetles than traps bordered by other crops. Prevailing winds were determined during July and August by the Agricultural Environmental Monitoring System (AEMS) located at the Tidewater Research Center, Suffolk, but the relationship between trapping beetles with pheromones and prevailing winds has not been fully determined.

THE EFFECTIVENESS OF IMAZALIL FOR CONTROLLING BLACK ROOT ROT IN BURLEY TOBACCO. Lawrence P. Specht\*, Gary J. Griffin\*, and John J. Reilly\*. Dept. of Plant Pathol., Physiol., and Weed Sci., VPI & SU, Blacksburg and Southern Piedmont Res. & Continuing Educ. Ctr., VPI & SU, Blackstone, VA. Black root rot, caused by Thielaviopsis basicola was found to be the primary disease associated with stunting of burley tobacco in southwestern Virginia. A field experiment was conducted on a commercial burley tobacco (cv. B21-Kyl0) field heavily infested with T. basicola. The fungicide imazalil (Fungaflor® 75WSP) was applied one day after transplanting by drenching the soil around the base of each plant with 50 ml of a solution containing 0, 250, 750 or 1,500 µg a.i./ml. All concentrations of imazalil failed to reduce the severity of black root rot compared to the control treatment. However, a laboratory study showed that imazalil was highly effective at inhibiting the in vitro growth of T. basicola, with 17 and 95% reductions in radial colony growth occurring when a vegetable-juice agar medium was amended with 0.001 and 0.1 µg a.i./ml, respectively. The results of these studies indicate that imazalil, while effective for inhibiting T. basicola in agar media, is apparently not effective (at the concentrations tested) for controlling black root rot in burley tobacco in Virginia.

THE EFFICACY OF SOME FUNGICIDES AFTER LONG-TERM STORAGE. Lawrence P. Specht\* and R. Jay Stipes. Dept. Plant Pathol., Physiol., & Weed Sci., VPI & SU, Blacksburg, VA. Eight fungicides, varying in age after accession, were evaluated for their ability to inhibit the in vitro growth of selected fungi. New and old compounds were incorporated into agar media at concentrations of 0, 0.01, 0.1, 1.0 and 10.0  $\mu\text{g}$  a.i./ml. *Sclerotinia minor* was used to test Terraclor<sup>®</sup>, Benlate<sup>®</sup>, Botran<sup>®</sup> and Rovral<sup>®</sup>. *Phytophthora boehmeriae* was used to test Captan<sup>®</sup>, Apron<sup>®</sup> and Terrazole<sup>®</sup>. *Ceratocystis ulmi* was used to test the antimycotic compound nystatin. Five-mm<sup>2</sup> agar plugs were removed from the margins of actively growing colonies and placed onto 9-cm diam. petri plates containing fungicide-amended agar media (25 ml/plate). Plates were incubated at 25 C for 4 (*S. minor* and *P. boehmeriae*) or 6 (*C. ulmi*) days prior to measuring radial colony growth. The efficacy of the old compounds, which had been stored for 2-16 yrs either at room temperature (ca. 25 C) or -5 C, were usually similar to the new compounds. One especially noteworthy finding was that the efficacy of an 11-yr-old sample of nystatin (stored at -5 C) was the same as a new sample. The results of these studies indicate that these fungicides apparently have relatively long shelf lives when stored dry and/or cold.

THE EFFECT OF ROOT SEVERANCE STRESS ON GROWTH OF PIN OAK (*QUERCUS PALUSTRIS*) AT BLACKSBURG, VA. R. J. Stipes, J. L. Ratliff, R. B. Flinchum and R. Cu. Dept. Plant Pathol., Physiol. & Weed Sci., Virginia Tech, Blacksburg 24061.

Abiotic (non-living) components of the comprehensive stress complexes that landscape trees endure around human settlements and on cityscapes must be accorded the "most devastating" status. Building contractors who "carve out" housing developments in established forested areas commonly destroy tree roots and damage trunks and branches which effect destructive consequences on tree growth, general health and normal longevity. We used 15-yr-old pin oak (*Quercus palustris*), planted about 1.5 m apart, in a local research plot. We simulated construction damage by severing 50% or 100% of root laterals or by girdling the bole in April, 1985, using ten randomized replicates per treatment. Growth repression was monitored in March, 1986, in which we recorded differences in tree diameter as the growth parameter. Average increases in diameters were 1.5 cm for control trees, 1.1 cm for trees whose lateral roots were 50% or 100% severed, and 0.8 cm for girdled trees. This documents one specific stress that impacts on landscape tree health, not to mention additional future growth repression and other pathological sequelae such as discoloration, decay and insect attack.

THE EFFECT OF REDUCED NOCTURNAL TEMPERATURE AND FEED ADDITIVES ON THE PERFORMANCE, SCOURING INDEX AND IMMUNE RESPONSE OF WEANLING PIGS. H. Swinkels\* & E.T. Kornegay, Dept. of Anim. Sci. & C. Shipley\*, Dept. of Large Anim. Clin. Sci., Va. Polytechnic Inst., Blacksburg, Va. 24061.

A 2 x 3 factorial arrangement of treatments was used to measure the effects of nursery temperature and feed additives on health and performance of weanling pigs. Pigs (n=120) were housed in one of two nurseries maintained at a constant (29.5 C; reduced 2 C weekly) or reduced nocturnal (RNT) temperature after week 1. In RNT, temperature was reduced 6.3 C, 4.7 C, 4.2 C and 3.3 C between 2000 h and 0800 h during weeks 2 through 5 of the experiment, respectively. The three diets were: basal (B), B + Mecadox (MEC), and B + ASP250 (ASP). MEC and ASP increased weight gain and feed intake compared with pigs fed B (P<.05) with the effect of MEC greater than that of ASP (P<.05) during the first three weeks. MEC increased feed efficiency compared with pigs fed B or ASP (P<.05). Compared with pigs fed B, MEC decreased the incidence and severity of scours in weeks 1 to 4 (P<.05), while ASP decreased the incidence and severity of scouring in week 4 only (P<.05). Hemagglutination titers against sheep red blood cells were not different between pigs fed the three diets or housed in the different nurseries (P>.10). RNT decreased (P<.10) weight gain, but not feed intake, and prolonged the duration of scouring. In summary, energy savings resulting from lowering night time temperature may be offset by small reductions in performance and prolonged scouring. MEC appeared to be more effective than ASP as a growth promotant and in reducing postweaning scouring.

**MICROSCLEROTIAL RECOVERY OF CYLINDROCLADIUM CROTALARIAE AND DEVELOPMENT OF CYLINDROCLADIUM BLACK ROT FOLLOWING TREATMENT OF NATURALLY INFESTED PEANUT FIELD SOILS WITH SODIUM AZIDE.** G. S. Tomimatsu\* and G. J. Griffin\*, Dept. of Plant Pathol., Physiol., & Weed Sci., VPI&SU, Blacksburg, VA 24061.

Cylindrocladium black rot (CBR) is a serious fungal root disease of peanut in Virginia, and is caused by *Cylindrocladium crotalariae*, of which the microsclerotium is the primary survival propagule. Using naturally infested peanut field soils, under controlled conditions (25 C), a significant linear relationship ( $R^2=0.96$ ,  $P=0.0001$ ) was observed between the microsclerotial population density and five doses of sodium azide ( $\text{NaN}_3$ ). Based on this curve, the effective doses at which 5% and 50% of the initial microsclerotial populations were recovered, were 14.0 and 7.4  $\mu\text{g NaN}_3/\text{g soil}$ , respectively. In greenhouse soil temperature tanks (25 C), CBR development was reduced significantly ( $P=0.05$ ) for plants grown in *C. crotalariae*-infested soils treated with 7.5  $\mu\text{g NaN}_3/\text{g soil}$  or higher, compared to those plants grown in untreated soils. *C. crotalariae* was recovered from asymptomatic and symptomatic roots of plants grown in either non-treated infested soils, or soils treated with 2.5  $\mu\text{g NaN}_3/\text{g soil}$ . Results of these studies may provide valuable information for effecting approaches to CBR management.

**DIETHYLDITHIOCARBAMATE, A NEW PHOTOSYSTEM I ELECTRON DONOR OF MEHLER-TYPE HILL REACTIONS.** Brad L. Upham and Kriton K. Hatzios Dept. Plant Path., Physiol. & Weed Sci., VPI & SU, Blacksburg, Va. 24061. The use of artificial electron donors has been very beneficial in the study of the photosynthetic electron transport (PET) system and the interaction of herbicides with PET. We report on a new PSI electron donor, diethyldithiocarbamate (DEDTC). DEDTC does not accept electrons from the PET but can donate electrons to a photosystem I (PSI) Mehler reaction in the presence of the following PET inhibitors: DCMU, DBMIB, and bathophenanthroline. It cannot photoreduce PSI in the presence of cyanide, a PET inhibitor. These data indicate that the site of electron donation is at plastocyanin. Ascorbate is not required for DEDTC's ability to donate electrons to PSI. There is no photoreductant activity by DEDTC in ferredoxin/NADP Hill reactions. Superoxide dismutase inhibits DEDTC/DCMU or bathophenanthroline  $\rightarrow$  methylviologen/ $\text{O}_2$  Mehler reaction. Catalase does not recover the consumed  $\text{O}_2$  from a DEDTC/DCMU  $\rightarrow$  methylviologen/ $\text{O}_2$  Mehler reaction, indicating  $\text{O}_2^-$  has not been dismutating into  $\text{H}_2\text{O}_2$ . These results indicate that superoxide is required for DEDTC ability to donate electrons and therefore the photoreductant ability of DEDTC is limited only to Mehler type reactions. (Supported by a Grant from the Jeffress Memorial Foundation, Richmond, VA)

**EGGPLANT CONSUMPTION BY LARVAE OF THE COLORADO POTATO BEETLE.** Karen M. Vail, Dept. of Entomology, Va. Polytechnic Inst. and St. Univ., Blacksburg, VA 24061 and J. H. Lashomb\*, Dept. of Entomology and Economic Zoology, Rutgers Univ., New Brunswick, NJ 08903. Eggplant consumption by larvae of the Colorado potato beetle, *Leptinotarsa decemlineata* Say, was observed at constant temperatures of 20, 23, 26, 29 and 32°C. There were no apparent feeding trends for the second and third instars. However, the fourth instars consumed more at 20°C than at 29 or 32°C. Developmental rates increased up to 29°C and then decreased at 32°C indicating the beginning of the upper thermal threshold. Female and male pupal weights were the greatest at 20°C. Larval equivalents compared the number of individuals of one instar at one temperature needed to equal the consumption of one fourth instar at another temperature. These larval equivalents will be used to rank eggplant fields in order of potential Colorado potato beetle larval damage.

## PREDICTING WEIGHT GAIN OF HEAT-STRESSED BROILERS WITH INCREASED AIR VELOCITY.

D. H. Vaughan, Dept. of Agricultural Engineering, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061, and N. E. Blackwell,\* The N.C. Alternative Energy Corp., Research Triangle Park, NC 27709. A lack of air circulation in broiler housing in the summer magnifies heat stress on the chickens, resulting in depressed bird appetite thereby decreasing weight gain. Conversely, research has shown that increased air velocity in the proximity of the broilers increases daily weight gain. Blower fans, used for ventilating broiler houses for many years, are being replaced with ceiling fans, which require less energy to operate while using air movement more efficiently. Ceiling fans produce wall jets which flow over the floor where the broilers are located. Using a computer model developed to describe the velocity profiles of the radial wall jets produced by commercial ceiling fans, broiler weight gain due to improved circulation can be predicted. Results show that, by improving weight gain, broiler market weight can be achieved in less time, resulting in a 10 percent increase in production while reducing fan energy consumption by 8 to 12 percent.

## SOIL PREPARATION FOR MINIMUM TILLAGE PRECISION SEEDING. D. H. Vaughan and L. M.

Schertz,\* Dept. of Agricultural Engineering, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. Conservation tillage has many advantages over conventional seedbed preparation, including reduced soil erosion and soil compaction, uniform high density plant stands, as well as energy and other cost savings. Conservation tillage systems for grain crops such as corn and soybeans and for forage crops are in widespread use. However, reduced tillage systems for crops having small and/or irregular shaped seeds have not been developed. Though some vegetable crops are transplanted, significant cost savings result when these crops are precision seeded. Soil preparation for precision seeding using reduced tillage methods is quite different for vegetable seeds compared to larger seeds such as corn or compared to grass seed. Field tests were conducted during 1985 using a prototype conservation tillage and planting system, which included notched coulters to clean the mulch cover crop from the soil surface followed by hydraulically-powered rotary tillers to prepare a 4-inch wide seedbed tilled 4 inches deep. A precision seed planter using punched belts for seed metering was used to seed broccoli in the seedbed. Results of the tests provided functional design criteria for a prototype machine to be used for seedbed preparation.

## DISTRIBUTION OF TRIAZINE RESISTANT WEEDS IN VIRGINIA. William K. Vencill and

Chester L. Foy, Dept. of Plant Path., Physiol. and Weed Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061. The purpose of this investigation was to determine the distribution of *s*-triazine resistant biotypes of common lambsquarters (*Chenopodium album* L.) and smooth pigweed (*Amaranthus hybridus* L.) in Virginia. A survey of all Virginia county extension agents was conducted in the winter of 1985. Collections of seed were made from suspected triazine resistant biotypes of common lambsquarters and smooth pigweed. Plants were grown from these seed in the greenhouse. Confirmation of triazine resistance was made by measuring chlorophyll fluorescence in the presence of atrazine. For further confirmation, spot checks were made using a greenhouse assay and a sinking leaf disc assay. Cross resistance to other *s*-triazines, *as*-triazines, and substituted ureas was determined for *s*-triazine resistant biotypes. There are *s*-triazine resistant common lambsquarters in 8 counties and smooth pigweed in 19 counties in Virginia. Most reports of triazine resistant biotypes have been from the northern and southwestern highlands of the state.

SCREW PRESS PARAMETERS FOR JUICE EXTRACTION FROM SWEET SORGHUM. T. T. Weitzel,\* J. S. Cundiff\* and D. H. Vaughan, Dept. of Agricultural Engineering, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Ethanol production from sweet sorghum is a means of meeting the liquid fuel requirements for Virginia farmers. Sweet sorghum is considered to be the crop best suited for ethanol production in Virginia because of its inherent ability to thrive in the Piedmont region. Sweet sorghum stalks were chopped at intervals of 0.5 and 1 cm. The chopping procedure disgorged the sugar-rich pith from the rind-leaf material. The pith and rind-leaf fractions were then separated using a vibratory screen. Several system operating parameters were investigated to determine the optimum values for maximum sugar extraction. The percentage of fresh weight separated in the pith fraction ranged from 60 to 85 percent, and the maximum extraction of juice was achieved with a single pass of the 80 percent pith fraction through a screw press.

TIMING OF INSECTICIDES FOR OPTIMUM CONTROL OF COLORADO POTATO BEETLE IN POTATOES. Geoffrey Zehnder, Va. Polytechnic Inst. & State Univ., Painter, Va. 23420. Cyfluthrin, fenvalerate, and oxamyl + carbofuran were the most effective insecticides tested for control of all life stages of Leptinotarsa decemlineata (Say). Rotenone and cryolite gave adequate control of small and large larvae. Treatments where different insecticides were alternated during the growing season resulted in commercially acceptable control and tuber yield. Analysis of L. decemlineata age distribution revealed that one specific life stage is predominant at any given time during the growing season. Choice of an insecticide can then be made based on the life stage present.

## Astronomy, Mathematics, and Physics

AN IMPROVED MAGNETIC SCATTERING AIR TABLE EXPERIMENT. T. T. Bateman and G. R. Taylor, Physics Department, James Madison University, Harrisonburg, VA 22807. An advanced undergraduate laboratory investigation of magnetic dipole-dipole scattering on an air table will be presented. The relationships between the distance of closest approach and the dependance of the scattering angle on impact parameter will be compared with an appropriate theoretical model. An improved magnetic launcher and small light emitting diode circuit which fits easily onto a magnetic puck will be presented.

SOLUTION OF THE HAMILTON-JACOBI EQUATION FOR SINGLE LINK ROBOT ARM USING SYMBOLIC MANIPULATION LANGUAGES. Alkesh Punjabi and James Bivins, Dept. of Math., Hampton Univ., Hampton, VA 23668. First the Lagrangian  $L$  for single link robot arm is set up in the fixed system of coordinates. Then the Hamiltonian  $H$  and the Hamilton's equation of motion are obtained. Hamilton-Jacobi equation for the characteristic function  $W$  is set up. H-J equation is solved in closed form. All these steps are done using the symbolic manipulation languages MACSYMA and SMP. (Supported by NASA under MACSYMA project.)

TWO-TONE FM SPECTROSCOPY. C. B. Carlisle, G. R. Janik, T. F. Gallagher, Dept. of Physics, Univ. of Va., Charlottesville, Va., 22901. A new method for performing high frequency, visible FM spectroscopy using low frequency detection is demonstrated. Using this technique, a detection limit of  $323 \mu\text{Torr} \cdot \text{m}$  (path length) has been established for pressure-broadened  $\text{NO}_2$ . This corresponds to a differential absorption of  $1.0 \times 10^{-5}$ .

**CANONICAL PERTURBATION THEORY AND THE ANHARMONIC OSCILLATOR.** Don Chodrow\*, Dept. of Physics, James Madison Univ., Harrisonburg, Va. 22807. Standard perturbation expansions for the motion  $x(t)$  of a nonlinear oscillator (force function  $F = -m\omega_0^2 x - m\epsilon x^n$ ) contain unphysical secular terms which grow with time and which make the motion appear unbounded. The secular terms must be eliminated by the Lindstedt renormalization procedure, a cumbersome if simple method, which demonstrates an amplitude dependent shift in the frequency of vibration. A not too well-known perturbation method using the canonical transformation to the action-angle variables of the linear problem as a starting point eliminates the problems with the secular terms. Any secular terms which ultimately appear in the expression for  $x(t)$  do so harmlessly as the argument of a sinusoidal function. This results in a direct evaluation of the amplitude dependence of the frequency of vibration.

**AN EXPERIMENT TO TEST THE SPIN DEPENDENCE OF GRAVITY.** C.E. Goldblum, Univ. of Virginia, W.T. Ni, National Tsing Hua University, R.C. Ritter and G.T. Gillies, University of Virginia. The question of a possible spin dependence of the gravitational interaction arises from invariance considerations, but also from its presence in the other three known forces. We have in progress a test of spin dependence which uses cm-sized cylindrical masses of  $Dy_6Fe_{23}$  having about 0.5 net electron intrinsic spin alignment per atom at room temperature. These polarized spin bodies are used in a period sensitive torsion balance in such a way that their macroscopic spin vector can be reversed, thereby permitting differential measurements of the spin coupling strength. We shall discuss here some of the special features of this experiment including the need for careful electromagnetic shielding, temperature control, and torsion balance design. Additional details are found elsewhere.<sup>1</sup>

1. W.T. Ni, "Polarized-Body Experiments and Equivalence Principles," Proc. 4th Marcel Grossman Meeting on General Relativity, in press.

**MINIMIZATION OF ELECTROSTATIC INTERACTION ENERGY OF CONFINED POINT CHARGES.** William H. Ingham, Dept. of Physics, James Madison Univ., Harrisonburg, Va. 22807. Configurations are presented which minimize the interaction energy of various numbers of identical point charges confined to given regions of dimensionality 1, 2, and 3. The relationship between these configurations and a well-known theorem of classical electrostatics is discussed.

**ORBITAL ENERGY AND EVOLUTION OF IO, EUROPA, AND GANYMEDE.** Kenneth C. Jacobs, Dept. of Physics, Hollins College, Roanoke, Va. 24020. Recent observational and theoretical research with S.J. Goldstein, Jr. (Univ. of Va.) and R.J. Greenberg (Planetary Sci. Inst., Tucson, Az.) has led to a simple model for the orbital evolution of the three synchronized Galilean moons of Jupiter. The model obeys the Laplace resonance condition for the mean motions; the satellite orbits experience no net tidal torque from Jupiter; and only Io is subjected to tidal heating. By balancing energy flows and imposing conservation of orbital angular momentum in the Io-Europa-Ganymede system, we find excellent quantitative agreement between the reported excess infrared flux from Io (volcanos!) and the observed acceleration (spiralling in!) of Io's orbit as recently determined by Goldstein and Jacobs (Astron.J., in press). Our model indicates that this satellite system is currently evolving out of exact resonance. While Io is spiralling in toward Jupiter at a fractional rate of  $4.6 \times 10^{-10} \text{ yr}^{-1}$ , Europa is following it in at half that rate ( $2.3 \times 10^{-10} \text{ yr}^{-1}$ ), and Ganymede is slowly spiralling outward (at  $-2.3 \times 10^{-10} \text{ yr}^{-1}$ ).

A SUPERCONDUCTING MAGNETIC SUSPENSION FOR PRECISION MEASUREMENTS. P.H. Karen, R.C. Ritter and G.T. Gillies, Dept. of Physics, Univ. of Virginia, Charlottesville, VA 22901. A preliminary design for the superconducting magnetic suspension to be used in a null gravitational redshift experiment is presented.<sup>1</sup> In this experiment, a freely spinning rotor is used as an inertial clock and its redshift is compared with that of a hydrogen maser.<sup>2</sup> Such an inertial clock requires a drag-free environment for the rotor, and this makes a superconducting suspension necessary.

1. Will, Clifford, Phys. Rev. D 10, 2330 (1974).
2. Bernard, Bruce, Ph.D. dissertation, Univ. of Virginia (1985).

HYBRID (INTERFEROMETRIC) VERTICAL MAGNETIC SUSPENSION SYSTEM. Michael F. Kerrigan\*, Dept. of Phys., Univ. of VA., Charlottesville, VA 22901. The magnetic suspension has been used as an ultra-low friction bearing for many years. One of the inherent limitations of these systems is that existing position transducers produce considerable electronic noise at the front end of the servo loop resulting in a relatively poor signal to noise ratio and hence limits the stability of the suspended object. In a hybrid system the more rugged but noisy conventional sensor is used to establish suspension, after which the interferometric sensor is phased in for continued operation. In a classical photo-diode detection system a relatively large displacement from equilibrium is required to change the input signal resulting in a poor signal to noise ratio. The interferometric system coupled with the conventional system, however, would produce a much larger signal per given vertical displacement resulting in a greatly increased signal to noise ratio. Specifically this present study tested the properties of this position transducer and developed the means of applying the fringe signals to a practical suspension.

USE OF BETA EMITTERS IN THE TREATMENT OF SELECTED POLLUTANTS, Taehong Kim and Donald A. Whitney, Department of Physics and Engineering Studies, Hampton University, Hampton, VA 23668. Beta emitters and electron beams have been used in many different applications. We are developing a computer simulation to investigate the application of a natural source of electrons, preferably a nuclear byproduct, to the treatment of atmospheric pollutants in smoke stack effluents. It is known that electron beams have been used to assist with the removal of SO<sub>2</sub> and NO<sub>x</sub> from smoke stack effluents in combination with electrostatic precipitators, scrubbers, water and ammonia catalysts. The problem to be presented involves the solving of chemical kinetics equations for various initial conditions and scenarios. The work was supported by Battelle Pacific Northwest Laboratories Contract # B-H7476-A-P.

NEW SOFT X-RAY SOURCE FOR SUBMICRON LITHOGRAPHY, Geo W. Lee and Kwang S. Han, Department of Physics and Engineering Studies, Hampton University, Hampton, VA 23668. Development of a new type of soft X-ray source (Hypocycloidal Pinch Device, HCP) suitable for submicron lithography was initiated. Preliminary results obtained with X-ray film and scintillation detectors show that operational conditions suitable for producing the magnitude of X-ray intensity, pulse width, and source dimensions that satisfy the requirements for soft X-ray lithography can be attained. In addition, a Dense Plasma Focus device was investigated for production of X-rays for comparison with those produced by the HCP.

THE NUCLEON-NUCLEON INTERACTION AS A COMPOSITE SYSTEM, Soon Park and W. W. Buck, Department of Physics and Engineering Studies, Hampton University, Hampton, VA 23668. We calculate Nucleon-Nucleon phase shifts employing a hybrid model containing the Reid Potential and the following phenomenological quark potential:

$$V(r) = -\frac{8}{3} g r [n(n-6) + s(s+1) + 3I(I+1)].$$

The numerical calculations employ the Nourmerov method.

NUMERICAL MODELING OF RF DRIVEN JOSEPHSON JUNCTIONS. Dorn W. Peterson and Alan Coleman\*, Dept. of Physics, James Madison Univ. Harrisonburg, VA. 22807. Josephson junctions hold the promise of providing active devices for use in the construction of fast analog and digital circuits which can operate at liquid helium temperatures. Because experimentally realizable junctions tend to have impedances of at most a few ohms they are generally coupled to room temperature instruments via an impedance transformer (generally a cavity or a microstrip transformer). Previous methods of modeling the interaction of the Josephson junction with the transformer have been computationally inefficient or physically unrealistic. A numerically efficient algorithm which accurately models a physically realizable system will be described. Some preliminary results of the modeling will be given. (Supported by grants from the Thomas F. and Kate Miller Jeffress Memorial Trust and from the Research Corporation)

A CONVERGENT VOLTAGE CONTROLLER FOR THE MILLIKAN OIL DROP EXPERIMENT. Andrew Jackson\*, Alan Coleman\*, Melanie Guarini\*, and Joseph W. Rudmin\*, Physics Department, James Madison University, Harrisonburg, VA 22807. The Millikan Oil Drop Experiment, the only experiment doable in an introductory physics laboratory which shows the properties of a single atomic particle, is difficult to perform because of the need to simultaneously watch a particle and adjust the capacitor voltage. This results in over-correcting the voltage so that the successive voltages fail to converge to a limit. A voltage controller consisting of an R-2R ladder D-to-A converter controlled by eight switches was constructed and tested on the Oil drop experiment by several experimenters. Rather than turning a dial to adjust the voltages, the student flips a switch. If this results in the rising target drop starting to descend, the student resets the switch and moves his finger to the next lower order switch. Adjustment of eight switches can control the voltage within half a percent. Another advantage is the ability to re-position a drop without losing the accumulated voltage. The circuit and a comparison of results will be presented.

RECENT ADVANCES IN PHYSICS, Raymond A. Serway, Department of Physics, James Madison University, Harrisonburg, VA 22807. There has been astounding progress in physics over the past two decades. Educators at all levels should attempt to incorporate important developments and discoveries in their courses whenever possible. One example which will be presented is the recent reanalysis of the Eötvös experiment which supports the existence of a non-Newtonian repulsive force.<sup>1</sup> The reported differences between the geophysical and laboratory values of the gravitational constant  $G$  is offered as further evidence of such a non-Newtonian coupling. If time permits, other recent advances will be reviewed, such as the technique of tunneling spectroscopy, the quantized Hall effect, and discoveries in elementary-particle physics.

<sup>1</sup>E. Fischbach, et. al., Phys. Rev. Lett. 56, 3 (1986).



PHASE SHIFTS ON REFLECTION FROM THIN FILMS. Billy W. Sloope, Dept. of Phy., Va. Commonwealth Univ., Richmond, Va. 23284. Phase shifts on reflection from surfaces contribute an equivalent path length to actual optical path lengths and are important in interferometry. Many techniques have been employed to measure phase changes on reflection and transmission in order to calculate optical constants and film thickness. Variation on a simple interference technique has been used for this purpose. Films are deposited on transparent substrates and one edge is overcoated. At the coated and overcoated edges the apparent and actual film thicknesses are measured. Any difference is due to relative phase changes on reflection. When these edges are viewed through the substrate a fringe shift is observed which can only represent phase differences upon reflection at the film-surface combinations. With these four measurements, and the optical properties of the substrate, phase change on reflection are determined for the film material and its index of refraction and absorption coefficient calculated. Results for various materials will be presented.

PION ABSORPTION IN  $^3\text{He}$  ON AND ABOVE THE (3,3) RESONANCE, L.C. Smith, R.C. Minehart, R.R. Whitney, (Dept. of Physics, Univ. of Va.), D.F. Geeseman, H.E. Jackson, J.P. Schiffer, B. Zeidman (Argonne National Lab.), D. Ashery, M. Moinester (Tel-Aviv Univ.) E. Piasetsky (LAMPF, Los Alamos), S. Levinson, S. Mukhopadhyay, R. Segal (Northwestern Univ.), B. Anderson, R. Madey, J. Watson (Kent State Univ.) The ( $\pi^+$ , pp) and ( $\pi^-$ , pn) reactions on  $^3\text{He}$  have been measured at incident energies of 350 and 500 MeV. Preliminary angular distributions of differential cross sections are presented. Both reactions show an asymmetry about 90 degrees in the c.m. system of the absorbing pair. Contributions from three-body processes are discussed. The ratio of absorption on  $^3\text{S}_1$  ( $T=0$ ) pairs to  $^1\text{S}_0$  ( $T=1$ ) pairs is shown to be smaller than what has been measured on the (3,3) resonance.

A DENSE PLASMA FOCUS PUMP SOURCE FOR DYE LASERS, Kyo D. Song and Kwang S. Han, Department of Physics and Engineering Studies, Hampton University, Hampton, VA 23668. A dense plasma focus (DPF) device was evaluated for establishing the feasibility of extending its pumping band for excitation of blue-green and near-uv lasers. The DPF pump source was studied in terms of current sheath velocity and spectral irradiance in the dye cuvette for different types of fill gas and fill gas pressures. A maximum blue-green laser output energy around 4.0 mJ for an input energy of 7.7 kJ was obtained during preliminary runs. Currently a feasibility study is being conducted for near-uv laser pumping using the dye, LD390. However, we found that the DPF pump power near the 355 nm band was an order of magnitude smaller than the threshold required. Methods for improving the pump power are under consideration. (Supported by the Army Research Office)

QUANTUM FIELD THEORETICAL ASPECTS OF MUON SPIN ROTATION. Carey E. Stronach, Dept. of Physics, Va. State Univ., Petersburg, Va. 23803. The phenomenon of muon spin rotation has developed into an effective technique for studying properties of condensed matter. This effectiveness arises from the relative ease of production of polarized beams of muons and the asymmetry of the angular distribution of the decay positrons relative to the muon's spin. Both of these properties arise from the parity violating character of the weak interaction. It is demonstrated that the utility of muon spin rotation in solid state physics depends upon two "happy accidents" of nature: (1) the meson with the lowest mass (the pion) is a pseudoscalar particle, and (2) the intrinsic handedness of the  $W^\pm$  boson. The former arises from the nature of quantum chromodynamics (QCD), the latter from the nature of the electro-weak interaction. (Supported in part by NASA grant NAG 1-416.)

## IMPROVEMENTS IN COMPUTER INTERFACED FRANK-HERTZ EXPERIMENT.

G. R. Taylor, Physics Department, James Madison University, Harrisonburg, VA 22807. A Leybold-Heraeus version of the Frank-Hertz tube has been interfaced to an Apple II microcomputer to interactively control the experiment and permit systematic variation of experimental parameters. Details of the circuitry, operation and software improvements will be presented. (The initial project work was performed as an advanced undergraduate project by H. E. Gilpin. J. W. Rudmin, Phys. Dept., James Madison University, consulted in the design of the current measuring circuits.)

## SELECTED PROPERTIES OF CHROMATIC POLYNOMIALS AND AN ASSOCIATED ALGORITHM.

Eileen Vaccaro\* and Gary Gies\*, Dept. of Math. and Comp. Sci., James Madison Univ., Harrisonburg, VA 22807. Introduced by Diane M. Spresser. The number of ways of properly coloring a graph  $G$  with  $x$  colors can be expressed as a polynomial in  $x$ ,  $P(G,x)$ , called the chromatic polynomial of  $G$ . Known theorems and properties of chromatic polynomials yield a known associated algorithm which computes the chromatic polynomial for any given graph  $G$  on  $n$  vertices. The algorithm utilizes the theorem

$$P(G,x) = P(G-e,x) - P(G:e,x),$$

where  $G-e$  is the graph obtained from  $G$  by deleting edge  $e$  and  $G:e$  is the graph obtained from  $G$  by identifying or fusing the two vertices  $u,v$  incident with edge  $e=(u,v)$ . We introduce innovative approaches to this algorithm through the use of shortest path recursion and a property of sign uniformity for all empty subgraphs having  $k \leq n$  vertices (i.e., we show that the terms of the chromatic polynomial alternate in sign by showing that all empty subgraphs on  $k$  vertices,  $1 \leq k \leq n$ , in the recursive algorithm have the same sign).

## HARMONIC MODES AND CONFORMATIONAL SUBSTATES IN PROTEINS. A.S. Brill\* &amp; J. L.

Wagner\*, Dept. of Physics, Univ. of Va., Charlottesville, Va. 22901. A model based on conformational substates and harmonic modes is used to describe dynamic effects in proteins. Conformational substates are associated with natural frequencies lower than the natural frequencies associated with harmonic gates distributed along the normal coordinates of the conformational mode. With regard to conformational modes, effective force constants from Mossbauer measurements on iron in myoglobin and EPR measurements on copper in azurin are the same,  $6 \times 10^4$  dynes/cm. Salient features of the model are heuristically pictured as those of a pendulum colliding with a barrier consisting of  $n$  thermally activated gates, each with stiffness  $k$  requiring a contraction of at least  $x$  for the pendulum to pass. The activation energy for a conformational transition is then  $nE$  where  $E = kx^2/2$ . The elementary barriers along the conformational mode path are amino-acid side chains with masses 15 to 100 daltons while the conformational modes are related to significant fractions of the protein with masses not less than 500 daltons. The transition rate is then proportional to  $T^\alpha f^n \exp(-nE/kt)$  ( $0 < \alpha < .5$ ) where  $f$  is the fraction of energetically accessible orientation space that permits transition.

## THE DEVELOPMENT OF A PHOTON COUNTING POSITION SENSITIVE PHOTOMULTIPLIER USING MICROCHANNEL PLATES AND CROSSED DELAY LINES.

Mark B. Williams, Stanley E. Sobottka, Dept. of Physics, Univ. of Virginia, Charlottesville, Va. 22901. In the field of protein crystallography, the desirability of studying macromolecules of large unit cell dimension has created the need for an imaging X-ray detector of high spatial resolution and large area. We are currently developing a position sensitive photomultiplier whose core components are 127 mm microchannel plates and a pair of orthogonal delay lines. It will have a sensitive area 122 mm in diameter and will have an overall spatial resolution of about 70 microns.

THE NEED FOR FURTHER EXPERIMENTAL EVIDENCE FOR EINSTEINIAN GRAVITY. Linda I. Winkler\*, Dept. of Physics, Univ. of Va., Charlottesville, Va. 22901. Although Einstein's General Theory of Relativity is a cornerstone of modern physics, there isn't a vast amount of experimental evidence to support it. The phenomena of the deflection of starlight passing the sun and the time delay due to gravitational potential strongly confirm the existence of curved space-time, but do not distinguish clearly between Einstein's gravity (a tensor field) and other non-metric theories. The precession of the perihelion of Mercury, a non-linear effect, could be explained by oblateness of the sun's field as well as by a tensor gravity. There is thus a need for more precise experiments to improve the understanding of gravity. Two such large-scale experiments currently being developed are the gravitational radiation detection program and the Stanford Relativity Gyroscope program. Smaller scale experiments involve placing limits on non-metric effects, such as violation of Einstein's equivalence principle and variation of G in time and position.

CHARACTERIZATION OF A HIGH POWER BLUE LASER PUMP SOURCE, D. D. Venable, W. J. Yi and J. H. Lee\*, Department of Physics and Engineering Studies, Hampton University, Hampton, Virginia 23668. We have utilized a hypocycloidal pinch device (HCP) to achieve lasing of a dye below a wavelength of 350 nm. This research represents the first time this device has been utilized to achieve lasing action in this wavelength range. The light that serves as the pumping source for the laser is produced when a plasma state is created in the working gas (Argon). The intensity, spectral characteristics, and rise time of the HCP light pulse are controlled by the gas pressure and the operating voltage of the system. We have optimized these parameters to achieve maximum lasing output for p-Terphenyl dye. At a pressure of 0.75 torr and an input energy of 550 J, we have obtained a laser output of 0.5 mJ at 337 nm with a band width of 3 nm and a pulse duration of 0.2 microseconds.

## Biology

THE DISTRIBUTION, STATUS AND FUTURE OF THE RED-COCKADED WOODPECKER IN VIRGINIA. Ruth A. Beck, Dept. of Biol., College of William and Mary, Williamsburg, VA 23185. Gary L. Miller\*, Dept. of Zoology, Weber State College, Ogden, Utah, 84404; Mitchell A. Byrd\*, Dept. of Biol., College of William and Mary, Williamsburg, VA 23185. Red-cockaded woodpecker (*Picodes borealis*) population status and reproductive success were studied in southeastern Virginia from 1976 - 1984. A comprehensive survey of suitable habitat was conducted in 7 counties to determine present population of birds and to estimate past population of birds. A total of 43 colonies were located within the first two years. The number of active colonies decreased each year. The decline may be associated with changes in the quantity and quality of the habitat and perhaps interspecific competition. All information available indicates the Virginia population is less than 50 individuals. In view of the small number of birds remaining, it is believed that in order for the red-cockaded woodpecker to survive in Virginia all of the remaining colony sites be managed specifically for this species.

THE ROLE OF HABITAT PARTITIONING IN CHESAPEAKE BAY BY THE LOGGERHEAD (CARETTA CARETTA) AND KEMP'S RIDLEY (LEPIDOCHELYS KEMPI) SEA TURTLES. SARAH A. BELLMUND\* Dept. of Fisheries Sci., VA Inst. of Marine Sci., Gloucester Pt., VA 23062. Virginia waters and Chesapeake Bay are a major juvenile foraging habitat for sea turtles and are reflective of habitat partitioning between life stages of the group. These stages are described by Carr, Carr, and Meylan (1978) as occurring in developmental habitats. Of the stages described by Carr et al. turtles in Virginia waters are partitioned so that the immature stages forage within Chesapeake Bay, while large subadults and adults are found off shore during the summer foraging season. Loggerhead sea turtles in Chesapeake Bay have an average straightline carapace length (CLS) of 66.7cm (SD=10.8, N=238). Turtles found on coastal beaches have a CLS of 72.3cm (SD=17.4, N=46). Aerial surveys show that animals moving along the coast during migration are of many sizes. This distribution changes during the summer when primarily large turtles are seen off shore.

CUTICLE PROTEIN BINDING TO CATECHOL POLYMERS BY THE AMERICAN COCKROACH. Patricia Bey, T.D. Kimbrough and R.R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. A catechol-containing polymer has been subjected to molecular sieve chromatography on polyacrylamide gel. Analysis via the Folin-Wu test has shown a molecular weight range between 1500 and 5000 daltons. The polymer binds cuticle proteins from the American cockroach. Previous studies have shown that the injection of 10 µg into newly-ecdysed animals is lethal. Interecdysial animals are also susceptible when given slightly higher doses. The possible mode of action of the polymer is discussed.

ORIGIN OF A HYBRID POPULATION OF LONG-TAILED AND THREE-LINED SALAMANDERS IN THE PIEDMONT OF NORTHERN VIRGINIA. Walter Bulmer, Nat. Sci. Div., Annandale, VA. 22003. Long-tailed and three-lined salamanders were found to hybridize in a limited environment in the piedmont of Northern Virginia. The population of hybrids exhibit a variety of patterns and colors ranging from "typical" three-lined forms to "typical" long-tailed forms. This hybrid population is sympatric with the coastal plain three-lined subspecies, but is approximately 50 miles east of the nearest long-tailed subspecies. The unique habitat created by Bull Run River eroding a gorge through the piedmont, producing steep, north-facing slopes is comparable with habitats found at higher elevations in the Blue Ridge Mountains to the west. It is hypothesized that the appearance of the displaced long-tailed salamander types at the locality could result from flooding of mountain streams sending larva salamanders into lower elevations.

COMPARISON OF THE LIFE HISTORIES OF IMMATURE LOGGERHEAD AND RIDLEY SEA TURTLES IN THE CHESAPEAKE BAY, VIRGINIA. RICHARD BYLES, Va. Inst. of Marine Sci., Gloucester Point, VA, 23062. Sea turtles display three distinct life history stages marked by special habitats and ecology (Carr, Carr and Meylan, 1978, Bull. Amer. Mus. Nat. Hist., Vol. 162.). The post-neonatal developmental stage of immature sea turtles occurs in inshore, estuarine or reef habitats. The Chesapeake Bay is habitat for the immature stage of loggerheads (Caretta caretta) and Kemp's ridley (Lepidochelys kempi) which migrate to the estuary each spring. Adults and very small turtles of both species are conspicuously absent from the bay. Similarities between the two species were reflected in activity (foraging), residence seasonality (May through October), philopatry and migratory routes (coastal, nearshore). Also evident were contrasts in behavior, prey items and habitats. The duration of dive and respiration periods were shorter for ridleys than for loggerheads. Ridleys fed predominantly on blue crabs (Callinectes sapidus) and foraged over less area than loggerheads, which ate primarily horseshoe crabs (Limulus polyphemus). The difference in prey items was also reflected in habitat selection with ridleys preferring shoal areas of seagrass beds and loggerheads tending to deeper channels leading to river mouths.

N-ACETYL DOPAMINE-BOUND PROTEINS FROM THE AMERICAN COCKROACH. Robert W. Carneal, T.D. Kimbrough, R.M. Ottenbrite and R.R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Cuticle proteins from Periplaneta americana have been partially purified by molecular sieve chromatography and by cellulose ion exchange. Proteins above sixty thousand daltons have been separated into negative, positive and neutral proteins. Binding of N-acetyl-dopamine to soluble cuticle proteins has been followed by diborylcellulose affinity chromatography. Both dihydroxy- and diquinone structures have been eluted, suggesting that both beta and ring sclerotization occur.

OCCURRENCE OF AQUATIC FUNGI IN BROMELIAD LEAF BASES IN FLORIDA. William B. Clary, W. W. Martin, Dept. of Biol., Randolph-Macon Col., Ashland, Va. 23005, & J. H. Frank, Dept. of Entomology, U. of Fla., Gainesville, Fla. 32611. Twenty water samples collected from leaf bases of Tillandsia utriculata epiphytic at 5 and 10' heights on Quercus and Conocarpus, were baited with pollen for isolation of chytridiaceous fungi. Upon receipt each sample was divided into two subsamples each of which were placed in petri dishes and baited with sweetgum or pine pollen. Chytrids were observed to grow on pollen in 18 of the 20 samples and in seventeen of twenty subsamples baited with pine and nine of 20 subsamples baited with sweetgum pollen. All samples from Quercus contained chytrids while three of five samples at 5' heights and four of five samples at 10' on Conocarpus contained chytrids. Pure cultures of chytridiaceous fungi were obtained from five of the samples on 1/2 strength CMA medium. Four of the isolates were identified as a species of Rhizidiomyces, possibly R. bivellatus Nabel. The other isolate was identified as a species of Rhizophlyctis, possibly R. hyalina Karling.

STIMULATION OF SMALL MAMMAL REPRODUCTION IN THE FIELD WITH 6-MBOA. J.A. Cranford, Biol. Dept., Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061. Field studies where 6-MBOA has been added to field food hoppers demonstrate that reproduction of Microtus pennsylvanicus, Peromyscus leucopus and P. maniculatus can be stimulated during periods of low or no reproductive activity. Field studies on Peromyscus were conducted on two study grids at the Univ. of Va. Biological Station during the summers and on M. pennsylvanicus in the VPI&SU Agriculture farm during the winter of 1983 and 1984. Control and experimental grids (minimum size 1Ha) were established to be ecological replicates and the experimental grid had the supplemental ground laboratory chow treated with 40  $\mu$ gm of 6-MBOA/gram of chow. Food was replenished weekly over the experimental period. Within the Peromyscus study reproduction was stimulated to occur two weeks earlier than on the control grid. In addition, histological examination of the ovaries showed a significant increase in the number of secondary and tertiary follicles in those not already pregnant and an increase in litter size in pregnant females. In the Microtus winter studies, reproduction was stimulated to occur two months earlier which resulted in population density increases 1.75 times control grid densities.

RELEASE OF REPRODUCTIVE INHIBITION IN MALES FROM LABORATORY POPULATIONS OF PRAIRIE DEERMICE: THE ROLE OF CONTACT WITH FEMALES OR THEIR URINE. Susan Creigh and C. R. Terman, Dept. of Biol., College of William and Mary, Williamsburg, Va. 23185. Reproductively inhibited male prairie deer mice (Peromyscus maniculatus bairdii) were taken from laboratory populations and maintained singly in contact with reproductively proven females, their urine, or water painted in their cages for 10 days or 30 days. Population control males and reproductively proven colony males were also studied for comparison. The body, testes, and seminal vesicles weights as well as the histology of the seminiferous tubules and spermatids were compared between treatments. Contact with proven females accelerated the reproductive recovery of inhibited males compared to contact with proven female urine or water for 30 days. Conversely, contact with proven females for 10 days promotes the continuation of the population inhibited condition. (Supported by the Biology Dept. and NSF Grant).

A COMPARATIVE STUDY OF THE EFFECTS OF LIGHT AND TEMPERATURE ON IN VITRO DEVELOPMENT OF CATENARIA SPECIES, FUNGAL PARASITES OF MIDGE EGGS. Celine A. Daily and W. W. Martin, Dept. of Biol., Randolph-Macon College, Ashland, Va. 23005. The effects of light and temperature on in vitro development of two isolates each of Catenaria uncinata and Catenaria ramosa (parasites of midge eggs), and one isolate of Catenaria anguillulae (parasitic in nematodes and liver fluke eggs; saprophytic in vegetable debris) is presented. Vegetative growth in C. anguillulae ranged from 8-42°C with optimum growth occurring at 32°C. Vegetative growth in C. uncinata isolates ranged from 10 to 36°C (optimum growth at 32°C) while growth in C. ramosa isolates ranged from 14 to 22°C (optimum growth at 22°C). Constant darkness generally increased the amount of vegetative growth obtained with constant fluorescent lighting. Functional zoosporangia were formed by C. anguillulae throughout its vegetative growth range with optimum zoospore release occurring between 16 and 24°C. Zoosporangia were formed in C. uncinata between 12 and 30°C with optimum zoospore release at 20°C. Zoosporangium formation and zoospore release did not appear to be influenced by constant darkness or fluorescent lighting. Zoosporangia were produced over the entire vegetative growth range in C. ramosa, however zoospores were formed and released only at 20°C under conditions of constant darkness.

THE ROLE OF TACTILE CUES IN THE RELEASE OF REPRODUCTIVE INHIBITION OF FEMALES FROM LABORATORY POPULATIONS OF PRAIRIE DEERMICE. Kristie A. Deyerle and C. R. Terman, Dept. of Biol., College of William and Mary, Williamsburg, Va. 23185. Reproductively inhibited prairie deer mice (Peromyscus maniculatus bairdii) were removed from laboratory populations and paired with either (1) reproductively proven males from a production colony or (2) inhibited males from the same population. These pairs were placed in (a) "No-Contact" cages which permitted exchange of auditory, visual, and olfactory stimuli but prevented physical contact between members of the pair, or (b) cages in which all of the above forms of interaction were possible. Population control females and reproductively proven colony females were also studied for comparison. Histological analyses revealed that females prevented physical contact with males developed significantly fewer follicles than those in physical contact with males. (Supported by the Biology Dept. and NSF Grant).

SPECIES COMPOSITION OF FLEA POPULATIONS ON SOUTHERN FLYING SQUIRRELS, GLAUCOMYS VOLANS, FROM DIFFERENT ELEVATIONS IN VIRGINIA. R.P. Eckerlin and H.F. Painter, Nat. Sci. Div., Northern Va. Cmnty. Col., Annandale, VA 22003. A collection of 7215 fleas was analyzed from the southern flying squirrel, Glaucomys volans, from Caroline and Hanover counties in the Virginia Piedmont (elevation ±50m). Four species of fleas were found with Orchopeas howardi the dominant species at all times of the year and comprising 98% of the collection. Conorhinopsylla stanfordi, Epitedia faceta and Orchopeas leucopus made up the remaining 2% and were found chiefly in the colder months. Opisodasys pseudarctomys, a boreal flea whose true host is the flying squirrel, was not present in the piedmont populations. To determine if O. pseudarctomys does occur in Virginia, nestboxes were placed at 600m and 1350m elevations in suitable woodland habitat in Augusta and Highland counties of the ridge and valley province of Virginia. Subsequent collection of 3271 fleas from nestboxes included O. pseudarctomys which at 600m was dominant from December through March and at 1300m from September through March. O. howardi was the next most common and there were sharp population peaks of the less common species C. stanfordi and E. faceta in November and December. The flea populations studied from different elevations differ in species composition and dynamics. Opisodasys pseudarctomys is reported from Virginia for the first time.

EFFECTS OF OVIPOSITOR MORPHOLOGY AND SOIL PARTICLE SIZE ON OVIPOSITION SITE SELECTIVITY IN TIGER BEETLES (*CICINDELA*). Frank W. Ellis, Jr.\* and C. Barry Knisley, Dept. of Biol., Randolph-Macon Col., Ashland, VA 23005. In the 17 species *Cicindela* community of the Sulphur Springs Valley, Az., ovipositor components were positively correlated with beetle size but the proportions of these parts were not size related. Ratio analysis showed that species with long, narrow styli of nearly equal length oviposited in sand soil while those with short, broad styli which differed greatly in length oviposited in clay soil. Intermediate species oviposited in a variety of habitats. Considerable abrasion of the styli occurred as the reproductive season continued. This was most evident in the species ovipositing in clay soil. Results suggest that ovipositor morphology may be a primary mechanism for habitat selection in the species in this community. This may have resulted from habitat segregation and corresponding ovipositor morphology divergence due to food limitations and competitive interactions.

VIRGINIA BATS AND NONTRADITIONAL COLLECTING: WHAT CAN THEY TELL US ABOUT LIFE HISTORIES? Carolyn S. Evans\* and John F. Pagels. Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Nearly 300 specimens of bats were "collected" in 38 Virginia counties through a 16 month period. Many were taken in homes and most in areas of human population concentration. Eight of the 15 species known from Virginia were collected, with the big brown bat, *Eptesicus fuscus*, 60%, and the red bat, *Lasiurus borealis*, 31%, being most represented. Canine tip distance, forearm and metacarpal lengths as well as degree of ossification of the epiphyses were used for age/growth determinations and can provide considerable information about life histories. For example, our total female sample of *L. borealis* outnumbered males 3:1, a relationship reported in many parts of its range. Age, using epiphyseal closure as the criteria, indicated that ratio is true in all age classes and suggests it is not simply a manifestation of differential foraging by the sexes. Young to adult ratio of *E. fuscus*, 2:3, seems to reflect its year round residency and activity whereas the 2:1 ratio in *L. borealis* closely reflects the expected young to adult relationship of that species in the reproductive season. Despite the unusual sampling methods, these specimens can serve as a resource in chiropteran studies.

EFFECTS OF PHENOBARBITAL EXPOSURE DURING ADOLESCENCE ON THE HISTOLOGY OF THE CEREBELLAR CORTEX IN MICE. Lynda G. Farley\*, P. L. Dementi, and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, VA. 23005. Phenobarbital is frequently used in treating adolescent epileptic patients, but most research on the effects of phenobarbital exposure on the histology of the nervous system has been done prenatally or neonatally. In the present study, phenobarbital (40 mg/kg) was administered in the drinking water to experimental mice from puberty (25 days postpartum) through adulthood (4 months postpartum). The cerebellum was surgically removed, fixed by immersion in buffered paraformaldehyde and glutaraldehyde, embedded in glycol methacrylate, sectioned mid-sagittally at 3 microns, and stained with azure A and eosin B. Cells were counted using a 180 x 120 micron ocular reticule. The cerebellar cortex of phenobarbital-treated mice contained significantly reduced (t-test) densities of granular layer neurons in the peripheral and mid regions of cortical folia and of astrocytes in the molecular layer in the deep regions of cortical folia. Since the granular layer neurons are critical in local relay in the cerebellum, these observations are consistent with the reduction in motor coordination frequently observed in phenobarbital-treated human patients.

GLYCOCONJUGATE WITH TERMINAL ALPHA GALACTOSE: A PROPERTY COMMON TO BASAL CELLS AND A SUBPOPULATION OF COLUMNAR CELLS OF NUMEROUS EPITHELIA IN MOUSE AND RAT. Franklin F. Flint, Dept. of Biol., Randolph-Macon Woman's Col., Lynchburg, Va., 24503, Bradley A. Schulte and Samuel S. Spicer, Dept. of Pathology, Medical University of South Carolina, Charleston, S. C., 29425. Basal cells in epithelium lining striated and excretory ducts of salivary and lacrimal glands, tongue, esophagus, trachea, renal calyx, ureter, urinary bladder, urethra, epididymis and vas deferens stained selectively and intensely for content of a glycoconjugate with terminal alpha galactose. This galactocjugate appeared associated with the plasmalemma of basal cells. Basal cells with a galactocalyx formed an intermittent to continuous layer generally increasing in prevalence distally in glandular duct systems. A minor population of pyramido-columnar cells with cytosolic GSA I-B<sub>4</sub> reactivity occurred in striated ducts and appeared less numerous in intralobular excretory ducts and more prevalent in extraglandular ducts. The location and distribution of GSA I-B<sub>4</sub> reactive basal cells in diverse epithelia suggests that through their alpha galactocalyx they serve in maintaining the established composition of luminal fluid perhaps by impeding the transepithelial movement of fluid and ions.

THE EFFECTS OF SACCHARIN AND ASPARTAME ON PLAQUE FORMATION BY STREPTOCOCCUS MUTANS UNDER AEROBIC VERSUS ANAEROBIC CONDITIONS. Mark J. P. Freeman,\* P. L. Dementi, and W. W. Martin, Dept. of Biol., Randolph-Macon Col., Ashland, Va. 23005. The accumulation of S. mutans on a tooth's pellicle surface results in dental plaque. S. mutans, which feeds on sugars, has been proven to grow in some artificial sweeteners. Cultures of 8.5 ml yeast-sucrose medium and 1 ml of various saccharin and aspartame concentrations were inoculated with 0.5 ml of a 24 hour culture of S. mutans. These were incubated for 24 hours at 36°C under aerobic and anaerobic conditions. Optical density readings were taken of the suspended and connected bacterial growths. Statistics indicated that saccharin suppressed bacterial growth and inhibited the connecting process of the plaque, the magnitude of inhibition being proportional to the sweetener concentration. Aspartame also showed a slight inhibiting effect on the connecting process, but only under aerobic conditions. Overall, anaerobic conditions stimulated the production of connected and suspended S. mutans.

PRELIMINARY STUDY OF T3 PRODUCTION BY SEVERAL PERIPHERAL TISSUES IN THE QUAIL. Thomas B. Freeman and F. M. Anne McNabb, Dept. of Biology, VPI & SU, Blacksburg, VA 24061.

Studies in our laboratory have demonstrated that thyroxine (T4) to triiodothyronine (T3) conversion by hepatic 5'-monodeiodinase (5'D) plays an important role in the serum T3 concentrations characteristic of perinatal and post-hatching birds. In mammals, liver and kidney have high 5'D activity and produce up to 80% of the T3 in serum; other tissues produce less T3, but T3 retention within them may be functionally important (e.g. in brain and pituitary of hypothyroid animals). The objective of this study is to measure 5'D activity in different tissues (liver, kidney, brain, thyroid, pituitary, muscle) in adult Japanese quail to provide reference information for continued studies of thyroid development and the roles of thyroid hormones in tissue growth and maturation. Activity of two isozymes of 5'D is being measured in vitro in tissue homogenates incubated with abundant substrate (T4) and cofactor (dithiothreitol). Liver and kidney activities are relatively high. Brain activity is undetectable using the assay previously employed. We are experimenting with longer incubation periods for brain tissue and are performing assays from preliminary studies of the remaining tissues.



FLUOROMETRIC DETERMINATIONS OF SEROTONIN LEVELS AT TEMPERATURE AND pH OPTIMA IN THE DIGESTIVE TRACT OF THE COCKROACH. C. R. French, R. R. Mills, and T. D. Kimbrough, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. The gastrointestinal tract of the cockroach may be stimulated by applying various molar concentrations of serotonin (5-hydroxytryptamine, 5-HT) during perfusion. However, concentrations below  $10^{-3}$  M appear to be inhibitory. From experiments using Leucophaea maderae, it was determined that the optimum concentration of 5-HT was  $10^{-8}$  M. Optimum concentration was defined as the quantity of 5-HT required to produce maximum gut motility. An optimum 10 degree temperature range (27°C to 37°C) had been established previously for producing maximum contractile composite motility in Ghromphadorhina portentosa. This also proved to be the optimum temperature range for L. maderae. Serotonin also induced the formation of repeating groups or "clusters" of contractile peaks which were not apparent in the control gut sections. Preliminary reports of pH measurements taken from perfused gut sections have suggested a gradual but significant variation in the extended range between 27°C and 37°C.

THE EFFECTS OF EGF AND GHL ON PROTEIN SYNTHESIS AND AMINO ACID UPTAKE IN MORRIS 7777 HEPATOMA CELLS. Catherine G. Green\* and Rosemary Barra, Dept. of Biol. Sci., Mary Washington College, Fredericksburg, VA 22401-5358. The effects of the growth factors EGF (epidermal growth factor) and GHL (glycyl-histidyl-lysine) on DNA synthesis, protein synthesis and total protein content in randomly cycling as well as quiescent 7777 Morris Hepatoma cells were investigated. Both growth factors were observed to stimulate DNA and protein synthesis with maximum stimulation at concentrations of 2 ng/ml GHL and 10 ng/ml EGF. GHL and EGF were also observed to increase total protein content per cell after a 24 hour incubation. In all cases, the cells were more sensitive to stimulation by EGF than GHL. In quiescent cells, maximum stimulation of DNA synthesis was observed after a 15 hour incubation with GHL.

FUNCTIONAL ANATOMY OF THE UPPER REPRODUCTIVE TRACT OF A PLANORBID FRESH WATER SNAIL (Gyraulus sp.). Nancy D. Green\* and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, VA 23005. Adult snails were narcotized with Nembutol and fixed in 4% glutaraldehyde, 1% paraformaldehyde in 0.01 M phosphate buffer, pH 7.2. After rinsing in buffer, snails were decalcified in ascorbic acid/sodium chloride solution for 24 hours, embedded in low-acid glycol methacrylate, serially sectioned and stained with Azure A and Eosin B. The structure of the reproductive tract was reconstructed by tracing the sections onto sheets of modeling clay using a microprojector. The gonad lay in the inner body whorl and consisted of anastomosing tubules which merged perpendicularly with the hermaphrodite duct which ran along the length of the left side of the gonad. The tip of the gonad was larger than previous descriptions indicated and the tubules in that region were less regularly arranged than farther down the gonad, merging with the hermaphrodite duct radially. The hermaphrodite duct ran along the right side of the body, with a large number of small alveolar seminal vesicles attached to its wall a short distance from the gonad. The highly coiled tubular albumen gland connected with the hermaphrodite duct just before the hermaphrodite duct emptied into the large sac-like carrefour.

EFFECTS OF FIXATION AND STAINING PROTOCOLS ON THE STAINING OF GLYCOSAMINOGLYCANS (GAGs) IN THE CHICK EMBRYO. Nannette G. Grimes\* and Carolyn M. Conway, Dept. of Biol., VA Commonwealth Univ., Richmond, VA 23284. Limbs from 8-9 day chick embryos were fixed as follows: paraformaldehyde (PF) in phosphate buffer (PB), PF-cetylpyridinium chloride (CPC) in PB, PF-glutaraldehyde (GA) in PB, PF-GA-CPC in PB, PF-picric acid (PA) in PB, PF-GA-PA in PB, GA-alcian blue (AB) in PB, and GA-ruthenium red (RR) in cacodylate buffer. The fixed tissues were infiltrated with and embedded in glycol methacrylate. Two micron sections were stained in azure A-eosin B (pH 4.4 acetate buffer), Stains-All (pH 2.5 or 4.0 acetate buffer), or 1% AB (pH 1.0, 2.5, or 4.0 acetate buffer) for 1 hour or 24 hours. Additional slides were pretreated with acetate buffer (pH 1.0, 2.5, or 4.0) for 24 hours or with 0.1% trypsin in phosphate buffered saline (37 C) for 1 hour prior to AB staining. Results indicated that increased staining of extracellular matrix GAGs occurred following pretreatment with acetate buffer or trypsin or in tissues fixed in fixatives containing GA, CPC, AB, or RR.

THE INFLUENCE OF SALINITY ON THE INTERACTIONS BETWEEN AQUATIC CHROMOGENIC BACTERIA AND PATHOGENIC *VIBRIO* SPP. John L. Harris, Andrew S. Gordon, and Fred L. Singleton, Dept. of Biol., Old Dominion Univ., Norfolk, Va. 23508. Environmental parameters of an ecosystem determine the structure of any community. One such parameter, salinity, influences the biota of an estuarine system, especially microorganisms. *Vibrio* species e.g. *V. anguillarum* and *V. alginolyticus* are common denizens of marine systems and have been implicated as pathogens in aquaculture facilities which employ saline water. The aquatic chromogenic bacteria were previously described as having amensalistic behaviour toward the *Vibrio* spp. In this study, the effects of different salinity (5, 15 and 25 parts per thousand) on interactions between aquatic chromogenic bacteria and pathogenic *Vibrio* spp. were investigated. In all cases, when chromogenic strain AB27 was employed, populations of both *Vibrio* sp. were significantly ( $p < 0.05$ ) reduced. However, significant reductions of *Vibrio* populations by other strains was related to salinities. For example, when cultured with BS54, the population of *V. anguillarum* increased at 25 ppt, in all other combinations, reductions in *Vibrio* populations were observed. Therefore, aquatic chromogenic bacteria may be a means to control bacterial epizootics in aquaculture facilities.

STUDIES OF SOME NORTHERN VIRGINIA KATYDIDS I. Phyllis H. Hatch. Dept. of Biology, George Mason University, Fairfax, VA 22032.

Species of northern Virginia katydids separated aurally and sonographically by their songs are shown to have stridulatory files which differ in number of teeth and distance of tooth separation. This can be portrayed usefully by means of a graph. Using traditional taxonomic characters together with the characteristics of the file, it seems likely that new species remain to be described.

FACTORS INFLUENCING FEMALE REPRODUCTION IN TWO SPECIES OF PEROMYSCUS IN VIRGINIA. L.K.Hawkins and J.A.Cranford. Biol. Dept., Virginia Polytechnic Institute and State Univ., Blacksburg, Va. 24061. Two species of Peromyscus commonly occur in Virginia; while field data has been reported on their reproductive rates their reproductive potential remains relatively unknown. Two laboratory colonies (P.leucopus noveboracensis and P.maniculatus nubiterrae) were maintained over a two year period (1983-1985) and total reproductive effort was quantified. In conjunction with the laboratory colony a field population of P.leucopus was live trapped every 21-28 days during the reproductive season (Mar.-Nov.) to compare to the laboratory population. Within P.leucopus litter size and total litter mass are strongly correlated with maternal mass and within low parities (1-4) reproductive effort is strongly and positively correlated with litter size. Across all parities maternal mass accounts for 47% of litter size variation. In P.maniculatus total litter mass was not correlated with maternal mass and as litter size increased neonatal mass decreased. P.leucopus field populations had significantly smaller litter sizes with spring litter sizes larger than fall but no differences in reproduction occurred between years.

BIOLOGY OF RHIZOGLYPHUS ROBINI (ACARI : ACARIDAE) REARED ON BOT AND MEYER'S ARTIFICIAL MEDIUM. William J. Hefele, Jr.\* and Norman J. Fashing, Dept. of Biol., Col. of William and Mary, Williamsburg, Va. 23185. Individuals of the bulb mite, Rhizoglyphus robini, were reared from egg to adult at three temperatures (16, 27 and 35 °C) using Bot and Meyer's artificial rearing medium. Immature mortality was 32.5, 21.4 and 91% and development time from egg to adult 35.8, 10.8 and 11.2 days for 16, 27 and 35 °C respectively (development times were not significantly different for males and females).

At 27 °C, individuals were followed throughout life and data collected on survivorship and fecundity. Total longevity for males (86.7 days) was significantly different from that for females (42.2 days). Females oviposited an average of 661 eggs over an average oviposition period of 25.6 days, and the maximum number of eggs laid by a single female in a single day was 52. The intrinsic rate of increase ( $r_m$ ) was 0.2555, the finite rate of increase ( $\lambda$ ) 1.29, the mean length of a generation (T) 25.6 and the net reproductive rate ( $R_0$ ) 256. The population parameters estimated utilizing Bot and Meyer's medium are very similar to those found using peanuts as a food source by other researchers, but higher than those found using garlic bulbs.

DENSITY-DEPENDENT PREDATION ON A LOW DENSITY PREY SPECIES PAPILIO GLAUCUS (LEPIDOPTERA:PAPILIONIDAE). Anne P. Hoover, Dept. of Entomol., Va. Tech, Blacksburg, VA. 24061. David A. West, Dept. of Biol., Va. Tech, Blacksburg, VA. 24061. Many field studies of density-dependent predation have utilized prey species whose natural densities may reach infestation proportions. It is important to evaluate density-dependent predation at lower densities because many potential prey species do not occur in large numbers. The pupae of swallowtail butterflies (Papilionidae) occur at relatively low but variable densities. Pupae of the tiger swallowtail (Papilio glaucus) were subject to density-dependent predation when placed at low but different densities in replicate plots of natural forest. The potential for density-dependent responses was highly dependent on year-to-year changes in predator densities and site-specific predator densities.

IMMUNOCHEMICAL EVIDENCE FOR FAT BODY SYNTHESIS OF CUTICLE PROTEIN IN THE AMERICAN COCKROACH. K. H. Hurd, T. D. Kimbrough and R. R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Injection of soluble cuticle protein from the American cockroach into the rabbit elicited the production of antibodies. The rabbit antisera was tested against various radioactive cockroach organ homogenates for specificity. Cuticle, fat body and haemolymph were positive while midgut, muscle, and nerve were negative. Sterile tissue culture of fat body with  $^{14}\text{C}$ -leucine produced labelled proteins which strongly precipitated with cuticle antisera. The role of fat body in the synthesis of cuticle protein precursors is discussed.

THE EFFECTS OF ASPARTAME ON METABOLIC RATES, DIGESTIVE ACTIVITY AND SEROTONIN LEVELS IN ALBINO MICE. Parag Kanitkar, R. R. Mills and T. D. Kimbrough, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. A 12-week study was conducted to measure the effects of aspartame (APM) on metabolism and serotonin levels in mice. The animals were divided into four groups, including: (1) controls fed a normal diet (C), (2) mice fed a normal diet plus aspartame (APM) (3) mice fed a normal diet plus APM and l-tryptophan (TRY) and (4) mice fed a normal diet plus TRY. At the end of the first six week period it was found that no significant changes had occurred in any of the groups except the APM group whose metabolism had decreased by 27.38%. During the final six weeks, D-glucose was added to the drinking water of all groups. No change was observed in the metabolic rates of the C and APM/TRY groups, but groups APM and TRY, respectively showed an initial increase greater than 20%. However, during the last three weeks of the study, all groups showed about the same rate of metabolism. It is postulated that this was due to the regulatory effects of insulin whose release was triggered by glucose. Fluorometric measurements of intestinal serotonin levels have shown significant decreases following the administration of a dietary excess of APM.

A COMPARATIVE STUDY OF GROWTH AND DISTRIBUTION OF MICROPTERUS DOLOMIEUI (SMALLMOUTH BASS) IN THE NORTH ANNA AND THE SOUTH ANNA RIVERS, VIRGINIA. Mark A. King\*, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284; Robert J. Graham\*, Environmental Laboratory, Virginia Power, North Anna Power Station, P.O. Box 402, Mineral, Va. 23117; William S. Woolcott, Dept. of Biol., Univ. of Richmond, Va. 23173; and Jackson E. Jeffrey, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. A comparison was made of the growth and distribution of Micropterus dolomieu from the North Anna and the South Anna Rivers. Lengths of North Anna fish were significantly greater ( $p < .05$ ) for some year-classes at ages two, three, and four. The extensive smallmouth habitat in the North Anna may reflect the influence of Lake Anna, a North Anna impoundment. Influential factors include: (1) a constant minimal water release of  $\approx 1.1 \text{ m}^3/\text{s}$ , (2) increased water quality in the system, (3) decreased turbidity from storm runoff (4) increased fall and early winter temperatures. Distribution of smallmouth bass in both rivers was positively related to high streambed gradient.

EFFECTS OF AFLATOXIN RESISTANCE ON GLUTAMIC OXALOACETIC TRANSAMINASE AND ALKALINE PHOSPHOMONOESTERASE FROM Drosophila melanogaster. Maria Kiouppis, J. P. Chinnici, T. D. Kimbrough and R. R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Endogenous levels of two enzymes, alkaline phosphomonoesterase and glutamic-oxaloacetic amino transferase have been assayed in six strains of Drosophila melanogaster. Two relatively susceptible strains to aflatoxin B<sub>1</sub>, two naturally resistant strains and two laboratory-induced, highly resistant strains were studied. There appears to be no difference in alkaline phosphatase activity between any of the six strains. The two susceptible strains exhibited less amino transferase activity than the resistant flies.

PHYSIOLOGICAL CHANGES DURING MOLTING IN THE ROCK CRAB, CANCER IRRORATUS. Carol L. Klumpp & P.L. deFur, Dept. of Biol., George Mason Univ., Fairfax, Va. 22030. A 77 percent mean increase in wet body weight due to water uptake occurred during molting. There was an osmotic gradient between hemolymph and the external medium of 50 to 60 mOsm prior to (stages D<sub>3</sub> and D<sub>4</sub>) and during (stage E) molting and exceeded 70 mOsm in postmolt crabs (stages A<sub>1</sub> and A<sub>2</sub>). Premolt crabs exhibited a definite alkalosis which was accompanied by elevated total CO<sub>2</sub>. Total CO<sub>2</sub> decreased substantially following the molt, and this decrease occurred within hours of molting. The present data suggest that the mechanism for water uptake is the osmotic gradient, and that there may be additional water uptake just after molting has occurred.

FOOD HABITS OF THE BLACK CRAPPIE, POMOXIS NIGROMACULATUS, IN LAKE ANNA, VIRGINIA. Bonnie J. Larson, Dept. of Biology, Old Dominion Univ., Norfolk, Va. 23508. The food habits of black crappie were studied in Lake Anna, Virginia and the Waste Heat Treatment Facility (WHTF) which is adjacent to the lake. Fish samples were collected during April, June, August, October and November 1985. Insects were important in the diet of black crappie in all months sampled in the lake, but were important only during April and June in the WHTF. Threadfin shad was important in the diet of black crappie in all months sampled in the WHTF, but was much less important in the diet of crappie in the lake. These differences in diet may be due, in part, to seasonal availability of prey and the differences in length-class distribution of crappie observed between the lake and the WHTF.

SHALLOW WATER FISH POPULATIONS IN THE TIDAL FRESHWATER POTOMAC RIVER. R. J. Lewis & D. Nusbaumer, Dept. of Biol., George Mason Univ., Fairfax, Va. 22030. Fish populations were sampled in Pohick Bay, a part of the freshwater area of the Potomac River. A 50 foot beach seine was used at four different stations around the Bay. Eight samples were taken at each sampling period, four during the day, and four that same night. The night samples were taken to examine the diel distribution of fish in the Bay. A total of 32 seines were completed and 4,747 fish were caught, made up of 19 species. However, 90% of the total were of only seven species: Morone americana, Menidia beryllina, Lepomis gibbosus, Etheostomus olmstedii, Anchoa mitchilli, Motropis dudsonius, and Fundulus diaphanus, all of which are from different families. Over 50% were of two species: Morone americana (32%) and Menidia beryllina (26%). There were significant differences found within species between night and day catches, which reflect possible migration from shallow to deeper water or vice versa.

NEUROTRANSMITTER EFFECTS ON WATER TRANSPORT IN THE HINDGUT OF PERIPLANETA AMERICANA. Timothy A. Lohrman, R.R. Mills and T.D. Kimbrough, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. The effects of noradrenalin, acetylcholine and serotonin on gut motility and water transport were studied in the hindgut of the American cockroach, Periplaneta americana. The primary emphasis was placed on serotonin activity. This biogenic amine at  $10^{-6}$  M enhanced gut motility, causing an increase in the amplitude, frequency and duration of contraction. Noradrenalin was less stimulatory while acetylcholine had little effect. Fluorometric analysis of hindgut extracts showed a distinct peak at 470 nm which corresponded to spectra of authentic serotonin. Tissue concentrations varied between 0.72 ug and 2.71 ug of serotonin per 20 mg of hindgut. Serotonin had no effect on water transport by the hindgut. Neither hypo- or isoosmotic physiological saline nor the addition of glucose had any effect on serotonin stimulation. More water moved toward the hindgut lumen when sucrose was used to make an isoosmotic or slightly hyperosmotic media.

A COMPARATIVE STUDY OF THE EFFECTS OF LIGHT AND TEMPERATURE ON IN VITRO DEVELOPMENT OF COUCHIA SPECIES, FUNGAL PARASITES OF MIDGE EGGS. Kathleen A. McCardell and W. W. Martin, Dept. of Biol., Randolph-Macon College., Ashland, Va. 23005. Couchia is a genus of water molds (Oomycetes, Saprolegniaceae) parasitic in midge eggs (Diptera, Chironomidae). Preliminary observations of the effects of light and temperature on isolates of Couchia grown in vitro on Emerson's YpSs agar are reported. Vegetative growth of seventeen isolates occurred within an optimum temperature range of 18-28°C (av. 23°C). Several isolates had growth curves with two optimum temperature peaks. Sixteen isolates exhibited temperature maxima of 30°C while one isolate had a temperature maximum of 36°C. Constant darkness was noted to increase the amount of vegetative growth obtained with constant fluorescent lighting. Whereas all isolates produced appressorial complexes and zoosporangia over a wide temperature range, only two isolates produced functional gametangia. Lighting did not affect the growth or formation of asexual or sexual structures. Six isolates were classified into three groups on the basis of similarities and differences in the shapes and dimensions of their zoosporangia.

LIFE HISTORY PATTERNS IN A CENTRAL VIRGINIA ANURAN COMMUNITY. Joseph C. Mitchell, Dept. Biol., Univ. of Richmond, Richmond, VA 23173. Anurans worldwide exhibit a wide variety of reproductive modes. This diversity has made it difficult to categorize these animals into a manageable number of discrete life history groups. Collins (1975), who focused his attention on local adaptations of eight anuran species, deduced there were two primary life history patterns exhibited by the community he studied. Data derived from a contrasting wet and dry, two-year study of a central Virginia anuran community consisting of twelve species are examined to determine if this more diverse assemblage can be similarly partitioned with Collins' criteria. My results indicate his dichotomies can be used with some modification to categorize the life histories of the Virginia community. Life history correlates of the primary criterion, probability of metamorphosis, include body size, larval and adult survivorship, length of larval period, habitat type, maximum clutch size and age at maturity. These aspects are summarized for each of the twelve Virginia species.

SOLUBLE PROTEIN ANALYSIS IN TRANSPORT OF WATER IN THE CROP AND FOREGUT OF THE AMERICAN COCKROACH. Patricia A. Morrisette, T. D. Kimbrough and R. R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. A dual chamber system has been devised to analyze transcellular transport across the crop epithelia of the American cockroach. Volume changes are determined by the isotope dilution technique using  $^{14}\text{C}$ -carboxyinulin. Water does not appear to move as rapidly as originally anticipated, but in hydrated insects such as these, fluid is transported into the crop lumen more slowly due to the antagonistic action of serotonin. Conversely, in dehydrated animals water moves out of the crop into the haemolymph. Serotonin enhances water transport at physiological concentrations ( $1 \times 10^{-6} \text{ M}$ ).

A COMPARISON OF THE EFFECTS OF FRUCTOSE ON THE DEVELOPMENT OF ANABAENA AZOLLAE ISOLATED FROM FOUR SPECIES OF AZOLLA FERN; AS COMPARED TO THE EFFECTS ON THE FREE-LIVING CYANOBACTERIUM ANABAENA VARIABILIS. Deborah L. Neely-Fisher & R.W. Fisher, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Azolla is a water fern that contains the cyanobacterium Anabaena azollae within the cavity of the dorsal lobe of the leaf. The symbiosis is maintained through a mutual exchange of fixed nitrogen and carbohydrates. We have separated the system and have Anabaena azollae isolated from four species of Azolla fern growing in axenic culture. Once removed from the symbiosis and grown in culture the Anabaena change morphologically and physiologically. We have examined the effects of fructose on the growth and development of the Anabaena in order to simulate symbiotic conditions. We have found that concentrations of fructose up to 200mM stimulate heterocyst differentiation, concentrations up to 150mM stimulate nitrogen fixation rates, and that concentrations up to 125mM and greater, restricts growth.

SKELETAL ASSOCIATIONS OF THE MUSCADINE DARTER WITH OTHER PERCINA SPECIES OF SUBGENUS ALVORDIUS. Thomas M. Orrell and William S. Woolcott, Dept. of Biology, Univ. of Richmond, Richmond, Va. 23173. Nineteen characters of five skeletal components of nine species of darters Percina (Alvordius) were used to establish the relationship of the undescribed muscadine darter (Percina sp.) to other members of the subgenus. Pertinent skeletal structures were the coracoid, premaxilla, premaxillary teeth, neurocranium, number of vertebrae, and position of first dorsal and anal pterygiophores relative to the numerical sequence of vertebrae. According to a dissimilarity matrix (distance measure between standardized character and taxa) characters of the muscadine darter are most like those of the stripeback darter (P. notogramma) and the Roanoke darter (P. roanoka), and most unlike those of the Appalachia darter (P. gymnocephala). (Supported in part by a Univ. of Richmond Undergraduate Research Grant.)

PHYSIOLOGICAL COMPENSATION TO SHORT-TERM AIR EXPOSURE IN THE BLUE CRAB, CALLINECTES SAPIDUS. Anita Pease, & P.L. deFur, Dept. of Biol., George Mason Univ., Fairfax, Va. 22030. Respiratory responses to 4 h emersion were studied in the blue crab Callinectes sapidus. Postbranchial hemolymph  $O_2$  tensions ( $PO_2$ ) decreased rapidly during emersion, indicating an impedence of oxygen uptake at the gill. Exposure to air induced a respiratory acidosis which was accompanied by the accumulation of lactate, a major end product of anaerobic respiration. Lactate, which acts to increase oxygen affinity of the respiratory pigment, hemocyanin, increased substantially during emersion, suggesting a shift toward anaerobic metabolism during periods of emersion induced air exposure. Gas exchange and hemolymph flow at the gill may be limited by the collapse of gill lamellae in air.

ECOLOGY AND SYSTEMATICS OF THE SPHARAGEMON BANDED-WING GRASSHOPPER IN VIRGINIA. Samuel Perdue, T.D. Kimbrough and R.R. Mills, Dept. of Biol, Va. Commonwealth Univ., Richmond, Va. 23284. The statewide geographical and seasonal distribution of the banded-wing grasshopper genus, Spharagemon (Acrididae: Oedipodinae) has been studied. A northern species, S. collare extends southward into Virginia, but is rarely found. A southern species, S. cristatum has the state as a northern boundary, and is commonly collected. Morphological comparisons suggest little or no hybridization due to the rarity of S. collare. The distribution of three other species of Spharagemon is denoted and the possible occurrence of a subspecies is discussed.

ANALYSIS OF LARGE TERTIARY PROTEINS BINDING TO PROBABLE SEROTONIN RECEPTOR SITES IN COCKROACH HINDGUT. David Rasmussen, T. D. Kimbrough and R. R. Mills, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Radioactive  $^{14}C$ -serotonin (5-hydroxytryptamine) binds to various protein fractions from the hindgut of Periplaneta americana. Separation of the soluble hindgut proteins by molecular sieve chromatography resulted in radioactive binding to a number of proteins. The use of P-100, P-150, P-200 and P-300 polyacrylamide gel separated molecules into fractions of: (1)  $< 60K$ , (2) 60-100K, (3) 100-135K, (4) 135-200K and (5)  $> 200K$  daltons. Electrophoresis (PAGE) of each size range produced a series of label-bound protein.

REPRODUCTIVE STRATEGIES OF VIRGINIA MEADOW VOLES, COTTON RATS, AND HARVEST MICE. Robert K. Rose, Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23508. Mammals usually respond to living in temperate locations by breeding during the warm months but not during the winter months. Virginia is a southerly location for meadow voles, but a northerly location for hispid cotton rats. Monthly samples were collected for autopsy in an effort to learn whether voles and cotton rats had unusual breeding patterns that reflected these marginal locations. In addition, the smallest Virginia rodent, the eastern harvest mouse, was studied using live-trapping methods, in part to learn the details of its reproductive season. The patterns of breeding are related to pattern of body growth and fat deposition, as well as to what is known about metabolic costs of reproduction in these species.



PEPTIDE BINDING OF SEROTONIN BY TISSUE EXTRACTS FROM THE HINDGUT OF THE AMERICAN COCKROACH. David Rowles, R. R. Mills and T. D. Kimbrough, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Soluble hindgut proteins from the American cockroach, Periplaneta americana, were separated through sonication of the hindgut in 1.5% KCl, centrifugation at 7,000g and molecular sieve chromatography. It had been postulated previously that low molecular weight proteins and serotonin-binding peptides would be evident in the second peak representative of organic molecules eluted from the chromatography column. However, no low molecular weight proteins or peptides were seen during analysis. Whether this is due to the fact that no low molecular weight proteins were present, or the fact that the tests used were not sensitive enough to detect small amounts of protein has yet to be determined.

HEAVY METALS IN REINDEER LICHENS FROM TELEMARK, NORWAY. Patrick F. Scanlon and Norvald Fimreite, Department Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 and Telemark Distriktshøgskole, 3800 Bø i Telemark, Norway. Gray reindeer lichens (Cladina rangiferina) recovered from 9 sites in Telemark, Norway in 1983 had heavy metals (Cd, Cu, Pb, Zn) determined. Cd concentrations varied from 0.21 to 0.44 ug/g d.w., and did not vary among areas. Cu concentrations varied from 1.67 to 11.04 ug/g d.w. and varied ( $P < 0.05$ ) by area. Pb concentrations were especially high (8.93 - 23.41 ug/g d.w.) and varied by area ( $P < 0.05$ ). Zn concentrations varied by area ( $P < 0.05$ ) and ranged from 28.4 to 44.4 ug/g d.w. Cd and Pb values in lichens seemed substantially higher than those in tree leaves from the same locations. [Supported by NTNf, Oslo, Norway]

HEAVY METALS IN SMALL MAMMALS FROM TELEMARK, NORWAY. Patrick F. Scanlon, and Norvald Fimreite, Department Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 and Telemark Distriktshøgskole, 3800 Bø i Telemark, Norway. Small mammals were snap-trapped from 3 areas of Telemark, Norway in 1983 and heavy metal (Cd, Cu, Pb, Zn) concentrations were measured in their livers and kidneys. Species trapped were as follows: wood mice (Apodemus sylvaticus); voles (Microtus agrestis); and 2 shrew species (Sorex araneus, Sorex minutus). Cadmium concentration in shrews was an order of magnitude greater than those in wood mice and voles. Cd, Cu, and Pb were higher ( $P < 0.05$ ) in shrews than in voles and wood mice within study areas. Pb and Zn concentrations in voles varied by area. Zn concentrations in wood mice, voles and shrews varied ( $P < 0.05$ ) by area. [Supported by NTNf, Oslo, Norway]

THE INFLUENCE OF IODINE ON HORMONE PRODUCTION BY THE THYROID GLANDS OF QUAIL. Lana C. Stallard and F. M. Anne McNabb, Dept. of Biol., VPI & SU, Blacksburg, VA 24061.

Research in our laboratory has shown that despite a wide range of dietary iodine (I), Japanese quail hens and young maintain consistent serum T3 and T4 concentrations. My research will investigate how changes in thyroid dynamics maintain consistent serum T3 and T4 concentrations with high I intake. I used embryos (14 day) and 1 day chicks from eggs of hens on control diets (800 ug I/kg) or high I diets (1200 ug I/kg). Fertility was unaffected by high I but hatchability was reduced and incubation time increased up to 48 hours with high I. Thyroid weights were unaffected but body weights were reduced by high I availability, resulting in an increased WT/WB ratio. I am measuring thyroidal hormone content, after pronase digestion and hormone extraction, with a double antibody RIA. In control embryos and chicks, T4 predominates in the thyroid; T3/T4 ratios are 0.015. Preliminary measurements indicate high I does not alter thyroidal T3. Thyroidal T4 measurements are in progress. I also will measure peripheral T4 to T3 conversion to evaluate how extra-thyroidal events interact with hormone production by the thyroid to maintain serum hormone concentrations.



DEMOGRAPHIC CHARACTERISTICS OF WHITE-FOOTED MICE (PEROMYSCUS LEUCOPUS NOVEBORACENSIS) IN NATURAL POPULATIONS DURING A THREE YEAR PERIOD. C. R. Terman, Dept. of Biol., College of William and Mary, Williamsburg, Va. 23185. This report describes a three year portion of a continuing study of White-Footed mouse populations on an 11 hectare area. Nest boxes (264) and live traps (600) provided information on numerical fluctuations and reproductive rates. Reproductive organ analyses of animals sampled from the populations were also utilized. Mice nested in the boxes primarily from October through April. The number of adults recorded on the study area varied from more than 126 in March of 1983 to a low of 10 in November of 1984. Reproductive rates were high in March, April, September and October and low in June. Generally, ovaries, testes, and seminal vesicles were significantly larger ( $P < .05$ ) during September and October than during the other months, although, variations occurred between years. The peak population level in 1983 was associated with reduced reproduction and smaller reproduction organs. Males tended to precede females in exhibiting reproductive curtailment.

OBSERVATIONS OF RACCOON (Procyon lotor) PREDATORY BEHAVIOR ON WHITE-FOOTED MICE (Peromyscus leucopus). W. Thompson, E. Lilleleht and C. R. Terman, Dept. of Biol., College of William and Mary, Williamsburg, Va. 23185. Raccoons were presented with various foraging opportunities during a year-long study. The results indicate that raccoons will eat mouse chow and mice, with preference given to the chow. Raccoons have the dexterity to open mouse live-traps, as well as to catch mice which were released from traps. Several raccoons were observed to consume mice, though none ate mice exclusively if chow was available. There was no evidence of surplus killing, although the raccoons observed did seem to be opportunistic feeders. The results have implications to the accuracy of field population studies using the "mark-recapture" method.

EFFECTS OF IN VITRO MIREX ON ADRENOCORTICAL FUNCTION. Margaret L. Till, David Davenport, and Saeeda H. Khan. Dept. of Biological Sciences, Old Dominion University. The pesticide mirex has been shown to produce liver and adrenal enlargement after a single oral dose and to increase serum corticosterone values. To determine if the steroidogenic action was a direct one on the glands, we examined the effects of mirex administered in vitro on corticosterone production. Adrenal gland quarters from six to eight week old, male Sprague-Dawley rats were incubated in KRBG with 0.01 mg/ml, 0.001 mg mirex/ml of incubation media, or no mirex (basal). Basal glands had an absolute secretion rate of 0.56 ug corticosterone/ml incubation media. Glands treated with the lower level of mirex produced significantly more corticosterone (1.36 ug/ml). Those glands receiving the higher mirex dose released corticosterone (2.0 ug/ml) at levels significantly higher than either the lower dose glands or the basal glands.

EFFECTS OF CAFFEINE IN UTERO ON ADRENOCORTICAL FUNCTION IN THE NEWBORN RAT. M. L. Till and R. Rohlfing, Dept. of Biol. Sci., Old Dominion Univ. Caffeine in utero has been shown to reduce offspring growth and neonatal mortality in the rat. In adult rats it has a stress like effect, increasing serum epinephrine and corticosterone levels. This study examined the effects of in utero caffeine on adrenocortical function in the newborn rat. Female rats were injected with a caffeine solution (20mg/ml, dose 25 mg/kg BW) or sterile saline daily for one week prior to mating and throughout gestation. Newborn rats were sacrificed within 24 hours of birth. Trunk blood was analysed for plasma corticosterone. Adrenal glands were incubated in KRBG media with ACTH as a stimulant or without ACTH (basal). Adrenal glands from rat given caffeine in utero were significantly smaller than their saline-injected counterparts. Plasma levels of corticosterone were not significantly different in the two groups. In vitro basal corticosterone production was significantly higher in the caffeine treatment group, 43 vs. 32 ng/ml media. Glands from the saline-injected group increased corticosterone production significantly in response to ACTH; the increase in the caffeine group was not significant.

FOOD HABITS OF THE BAT, PLECOTUS TOWNSENDII VIRGINIANUS, IN VIRGINIA. Virginia M. Tipton, Dept. Biology, Radford Univ., Radford, VA 24142 & Virgil Brack, Jr.\*, WAPORA, Inc, 5700 Hillside Ave., Cincinnati, OH 45233. A maternity colony of Plecotus townsendii virginianus was studied for three years, from 1983 through 1985. Feces were collected weekly from the roost sites in the nursery cave from mid-April through late September. Food items were determined by examining fecal pellets for insect fragments. The insect parts were estimated as percentages of the total volume. The majority of insects identified were moths (Lepidoptera); they represented about 90% - 100% of the diet. Coleopterans were the next most abundant prey item, averaging 0.5% to 10 %. Analysis of the total diet throughout the period revealed no seasonal fluctuations. These bats seem to be moth specialists, with other insects taken incidental to foraging for the moths.

COMPARISON OF PHOTOSYNTHETIC PIGMENTS BETWEEN C3 AND C4 PLANTS ADAPTED TO SIMILAR HABITATS. M. G. Treuth\* and A. F. Conway, Dept. of Biol., Randolph-Macon Col., Ashland, VA 23005. The pigment levels in leaves of selected crop species (rye, barley, wheat, sorghum, sorghum x Sudan grass hybrid) were determined by in vivo spectrophotometry and by spectrophotometry of acetone and methanol extracts of leaves. No significant differences in concentrations of carotenoid, chlorophyll a, or chlorophyll b, or in carotenoid/chlorophyll a ratios were detected in plants grown under normal greenhouse conditions. Sorghum x Sudan grass hybrids grown under reduced light levels (under window screen or under green tissue paper) contained significantly (p less than 0.05, ANOVA) higher chlorophyll b concentrations and carotenoid/chlorophyll a ratios. With the exception of barley, all other species tested contained increased chlorophyll b levels and increased carotenoid levels when grown under reduced light levels, but the differences were not significant. These results indicate that different crop plants derived from grasses respond to reduced light levels in different ways, but no consistent differences in the responses of C3 plants (rye, barley, wheat) versus C4 plants (sorghum, sorghum x Sudan grass hybrid) were observed.

SELECTION OF A FIXATIVE FOR IMMUNOCYTOCHEMICAL DEMONSTRATION OF IMMUNOGLOBULIN G IN THE PREGNANT MOUSE UTERUS. Thomas P. Viering\* and Carolyn M. Conway, Dept. of Biol., VA Commonwealth Univ., Richmond, VA 23284. In an attempt to find a fixative that gives good staining of IgG in the pregnant mouse uterus, the following fixatives were investigated for their ability to preserve both morphology and the antigenicity of IgG: (1) 4% paraformaldehyde (PF) in 0.1 M phosphate buffer (PB); (2) 4% PF-1% glutaraldehyde (GA) in 0.1 M PB; (3) 4% PF-1% GA and 1% cetyl pyridinium chloride in 0.1 M PB; and (4) periodate-lysine-0.5% paraformaldehyde-1% glutaraldehyde. Fixed tissues were infiltrated with and embedded in glycol methacrylate. A direct immunoperoxidase procedure employing peroxidase labelled goat anti-mouse IgG was used to stain the antigen. Fixation with 4% PF in PB has resulted in good staining for the antigen and also gave reasonable preservation of morphology. The GA containing fixatives gave good morphological preservation but resulted in no staining for the antigen. We concluded that fixatives containing GA should not be used in immunocytochemical studies of the pregnant mouse uterus.

GROUND SKINKS AND MILKWEED BUGS: A TEST OF OLFACTORY RECOGNITION OF PALATABLE AND UNPALATABLE PREY. Anne C. Wells\* & Paul F. Nicoletto, Dept. of Biol., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061.

The objective of this experiment was to investigate the sensory modalities lizards use to recognize normal prey versus unpalatable and palatable novel prey. Ground skinks, Scincella lateralis, were randomly presented five different prey types, a palatable milkweed bug, an unpalatable milkweed bug, a dusted milkweed bug, a cricket covered with a milkweed bug extract, and a cricket. The lizards initial response to prey among the five treatments was similar, as there were no significant differences in the rates of tongue flicking prior to approach, latency time to approach, and number of approaches. Upon approach to within one centimeter, the lizards immediately attacked and ingested the control cricket. However, in the other four treatments, lizards first investigated the prey using olfaction as evidenced by increased tongue flick rates. All milkweed bug prey was apparently rejected on the basis of chemical cues. Crickets covered with milkweed bug extract received some protection, as only five of twelve crickets were ingested. Ground skinks predominantly rely on visual cues to identify normal prey, but when confronted with novel prey, rely heavily on olfactory cues.

LIFE HISTORY STRATEGIES OF WHITE-FOOTED MICE (PEROMYSCUS LEUCOPUS). Jerry O. Wolff, Dept. of Biol. Univ. of Va, Charlottesville, Va 22901. The behavioral and population ecology of white-footed mice were studied at the Mountain Lake Biological Station in southwestern Virginia from 1981 through 1985. The population ranged from a high of 38 mice/ha in 1981 to a low of 6 mice/ha in 1983 and increased to 17 mice/ha in 1985. From 1981 through spring 1985 the breeding season was bimodal with peak activity in April through June and September through October with a midsummer breeding lull. Mice bred throughout the 1985-86 winter. Litter size ranged from 3.3 to 3.5 young/litter and females averaged 1.4 litters. Most spring-born animals reached sexual maturity and bred in fall, except at high densities. The length of residency ranged from 5.7 to 15.6 weeks and was greatest for adults and juvenile females. Juvenile males tended to disperse from their natal site. Breeding adults were aggressive and territorial only during the high density year; adults were not aggressive toward juveniles. Home ranges were larger among males than females and at low than high densities. Food was not a factor limiting population numbers. Animals nested alone in trees or underground during summer, and communally underground during winter. Life history strategies of P. leucopus are discussed with respect to fluctuations in density and seasonal environments.

STUDY OF THE HOMOLGY OF FAT BODY ENDOSYMBIONTS IN DIFFERENT COCKROACH SPECIES. H.N. Wren and D.G. Cochran, Dept. of Entomology, VPI & SU, Blacksburg, Va 24061. Fat body endosymbiont bacteria are common to all species of cockroaches studied thus far. Their closely related physiology apparently contributes to the cockroach being a highly successful animal, although the exact nature of the bacteria has not been definitely established. Immunoelectrophoretic techniques were employed to study the relatedness of the endosymbionts from several species of cockroaches, and the genetic similarity of the bacteria is also being studied by DNA hybridization experiments. The results of these preliminary studies suggest that the endosymbiotic bacteria from several different cockroach species are related.

REPRODUCTIVE CHARACTERISTICS OF A CAPTIVE COLONY OF *PEROMYSCUS LEUCOPUS*.

Susan M. Yocum, Patrick F. Scanlon, MaryBeth Moss, and Walter E. Montz, Jr. Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. *Peromyscus leucopus* have been kept in a laboratory since 1971 at VPI & SU. The initial colony was established from wild pregnant females and wild males. New wild males have been periodically introduced. Records are kept to prevent inbreeding. Records of productivity of pairs kept in shoe-box cages were examined for the period 1984-1986. Mean litter size ( $N=218$ ) was  $3.59 \pm 0.08$  (S.E.). Mean young surviving to age 21 days was  $0.72 \pm 0.03$  ( $N=216$ ). The mean interval between successive parturition was  $49.96 (\pm 3.07)$  days. Generation from the wild did not affect litter size or viability of young ( $P>0.05$ ) but tended to effect ( $P=0.08$ ) parturition interval. Age of dam tended to effect litter size ( $P=0.06$ ). Size of litter (range recorded was 1-6) affected ( $P<0.01$ ) viability of litter with larger litters being generally less viable than smaller litters.

## Botany

EVALUATION OF SAMPLING METHODS TO DETERMINE DENSITY AND BASAL AREA OF TREES IN A HARDWOOD FOREST. H. S. Adams and M. L. Lipford, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422. In 1976, all trees greater than 2.4 cm DBH occupying a one hectare area in Alleghany County, Virginia, were measured and mapped. The stand is dominated by *Acer rubrum* (IV = 38.3) and *Quercus velutina* (IV = 16.6). Data were collected by two plotless methods (Bitterlich prism and point-centered quarter) and by quadrats for comparison with the full tally to determine accuracy of each method. Random points (19) were used for both the prism and quarter methods, and five quadrats (5 X 20 m) were established within the 1 ha stand. Among methods, chi-square values for goodness of fit by taxa were lowest for density (151.1), basal area (1.4), and importance value (2.4) for the prism method. The null hypothesis was accepted ( $p = 0.05$ ) for both basal area and importance value. Although all methods underestimated total density of trees, the quarter method had least error (6%). Both the quarter and prism methods underestimated total basal area (32.2% and 18.1%, respectively), whereas the quadrat method overestimated this attribute (30.6%). We recommend the prism method for rapid and satisfactory estimate of just basal area, as in timber cruising. For more comprehensive study of natural communities, however, we suggest the quadrat technique is still superior among the methods tested.

COMPARISON OF OLD-GROWTH AND SECOND-GROWTH RED SPRUCE STANDS IN THE ALLEGHENY MOUNTAINS OF CENTRAL WEST VIRGINIA. H. S. Adams, M. L. Lipford, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422, and S. L. Stephenson, Dept. of Biology, Fairmont State Col., Fairmont, WV 26554. Vegetation and soil characteristics from second-growth ( $66 \pm 4$  yrs) and old-growth ( $200 \pm 14$  yrs) stands dominated by red spruce were compared. Both stands were located within 2.5 km of each other at Gaudineer Knob, WV. The second-growth site (1,323 m) occupied a west-facing slope, the old-growth site (1,200 m) an east-facing slope. Soil characteristics in both stands were similar, except that soil moisture in the second-growth stand (322%) was more than twice that of the mature stand (143%). Only red spruce (IV = 99.7) and yellow birch were present in the tree (greater than 9.9 cm DBH) stratum of the second-growth stand, whereas nine species of trees were recorded in the old-growth stand (red spruce IV = 38.3). Both basal area ( $m^2/ha$ ) and density ( $N/ha$ ) of trees were higher in the younger stand. Bryophyte cover was greater in the second-growth stand, herb cover in the older stand. Decline in both radial and basal area increment of canopy red spruce trees has occurred in both stands since the 1960s.

THE GERMINATION OF SEEDS FROM SELECTED ORCHIDS. K. Baker and M.C. Mathes, Dept. of Biol., Coll. of William & Mary, Wmsbg., VA 23185. Experiments were designed to investigate orchid seed germination and subsequent plantlet growth and development. Seeds from terrestrial orchid capsules of Ponthieva racemosa and seeds of the epiphytic Cattleya bicolor v. brasiliensis were initially sown on selected media to determine germination percentages. Ponthieva showed the highest percent germination on the commercial medium and Cattleya had the highest germination percentage on modified Steinitz medium. The addition of hydrogen peroxide resulted in increased germination of the Cattleya seeds on each of the media, but decreased the percent germination of the Ponthieva seeds on most media. Sugar soaking resulted in increased germination percentages in Cattleya, but decreased the germination of Ponthieva. Sugar vacuum infiltration was less effective for both species of seeds. Subsequent protocorm (Ponthieva, Cattleya and Phalaenopsis) growth was most rapid for both species on Vacin and Went Orchid medium. This medium promoted the most rapid, normal development into plantlets. A hydroponic culture system was also investigated as a method of decreasing the time for plantlet development from the flask to greenhouse pots.

THE VIRGINIA WILDFLOWER PRESERVATION SOCIETY - A CHALLENGE TO VIRGINIA BOTANISTS. Dorothy C. Bliss, Dept. of Biology, Em., Randolph-Macon Woman's Col., Lynchburg, Va., 24503. The purpose of the Virginia Wildflower Preservation Society, organized in Virginia in 1982, is to promote the conservation and preservation of the native plants of Virginia. Activities to implement this purpose include conservation measures, public education, wild flower cultivation, landscaping with native plants, relocation of plants from communities threatened with destruction, research, rare plant inventories, cooperation with other organizations having compatible purposes and counsel to governmental bodies. The role of the professional botanist in these endeavors is discussed.

EFFECTS OF ELAIOSOME REMOVAL ON GERMINATION OF SEVERAL ANT-DISPERSED PLANTS Marion C. Blois, Dept. of Biol., No. Va. Comm. Col., Manassas, VA 22110 & L.L. Rockwood, Dept. of Biol., George Mason Univ., Fairfax, VA 22030. Some researchers have hypothesized that the removal of elaiosomes may stimulate germination in ant-dispersed plants. In a preliminary 1984 experiment reported by these authors with bloodroot (Sanguinaria canadensis) seeds, there was a 30% germination rate in seeds from which elaiosomes were manually removed compared to zero germination in seeds with intact elaiosomes. In Spring, 1985, S. canadensis, along with four other spring-blooming species (Viola pennsylvanica, Asarum canadense, Dicentra cucullaria and Trillium sessile) were examined in a similar experiment. For each species, elaiosomes were manually removed from one group of seeds and left intact in a second group of the same number. All seeds were placed in an incubator and subjected to seasonal temperature regimes in the dark. In V. pennsylvanica seeds, 48% germination was observed in seeds with intact elaiosomes and 46% with seeds with elaiosomes removed. Germination rates of 0-4% were observed in both test groups of other species. V. pennsylvanica germination appears to be unaffected by elaiosome removal. The effect of elaiosome removal in the other species appears to be questionable. Additional experiments with these species will be conducted in the Spring of 1986.

ANALYSIS OF LOW COPPICE VEGETATION AT BLANKET SOUND, N. ANDROS ISLAND, BAHAMAS. Ted Bradley, Catherine West\* and Barry Boyd\*, Dept. of Biology, George Mason Univ., Fairfax, VA 22030. Low coppice vegetation is comparable to the maritime scrub-thorn typically seen on the dry coasts of subtropical islands. Frequency, density and basal areas were calculated from sampling of the canopy. The three most dominant species in the canopy in descending order, are Metopium toxiferum (Anacardiaceae), Savia bahamensis (Euphorbiaceae) and Manilkara bahamensis (Sapotaceae). Based on frequency and density the three most dominant species in the subcanopy are Savia bahamensis (Euphorbiaceae), Coccoloba diversifolia (Polygonaceae) and Randia aculeata (Rubiaceae).

A SYSTEMATIC SURVEY OF TERPENES IN THE GENUS MAGNOLIA. Douglas A. Dederer, W. John Hayden, Dept. of Biol., Univ. of Richmond, Richmond, Va. 23173, & Stuart C. Clough, Dept. of Chem., Univ. of Richmond, Richmond, Va. 23173. The terpene content of 16 species and 5 hybrids of Magnolia were examined using soxhlet extraction with pentane and gas chromatography - mass spectroscopy for analysis. Over 250 compounds were found, 46 of which were sesquiterpenes. Whereas monoterpenes were found to be variable from specimen to specimen of the same species, sesquiterpenes proved to be fairly consistent between specimens of a species. The sesquiterpenes were also found to be consistent regardless of geographic origin of the specimen and, in the case of M. stellata, between different cultivars of a species. Analysis of several hybrids showed most to have sesquiterpene profiles which are subsets of the profiles of their parental species, suggesting genetic control of production of the sesquiterpenes. Little correlation was found between the sesquiterpene profiles of the species examined and the traditionally defined taxonomic sections of the genus.

PLANT-PARASITIC NEMATODES ASSOCIATED WITH DECLINING SPRUCE AND FIR TREES IN THE SOUTHERN APPALACHIANS. J. D. Eisenback, Dept. of Plant Path., Physiol. and Weed Science, Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24061, and K. M. Hartman, Dept. Plant Path., NC State Univ., Raleigh, NC 27650. Each of the eight major spruce-fir forests in the southern Appalachian mountains were surveyed to identify the incidence of plant-parasitic nematodes associated with declining trees. Sphaeronema sasserii was detected on the Great Smoky Mountains, Plott Balsam Mtns., Balsam Mtn., Black Mtn., Whitetop Mtn., and Mt. Rogers but not on Grandfather Mtn. or Roan Mtn. Both spruce and fir trees were parasitized and the nematode was nearly always found on declining trees above 1,800 in but not on healthy trees at lower elevations. More than 7,000 nematodes per gram of fresh root were recovered from infected roots 2 mm or less in diameter. Plant-parasitic nematodes may be a contributing factor in the slow decline of spruce and fir that has occurred in recent years. (Supported by Carolina Power and Light Contract No. XT-30000035.)

FLORAL MORPHOLOGY AND RELATIONSHIPS OF NEOWAWRAEA (EUPHORBIACEAE). W. John Hayden, Dept. of Biol., Univ. of Richmond, Richmond, Va. 23173. Neowawraea Rock is a rare monotypic genus endemic to the Hawaiian Islands. Recent studies of its wood anatomy prove it to be distinct from Drypetes Vahl with which it has been erroneously synonymized. The availability for the first time of pistillate flowers as well as examination of 41 collections from numerous herbaria permit more satisfactory resolution of the relationships of Neowawraea than has been possible in the past. The plants are large dioecious trees severely attacked by twig borers and, hence, many specimens are now senescent, but regeneration from stump sprouts is common. Flowers are borne in minutely bracted axillary clusters; perianth consists of five unequal sepals. Staminate flowers possess 5 stamens inserted between the lobes of the floral disk; a small pistillode is present. Pistillate flowers possess a 3(4) carpellate superior ovary atop a small floral disk; stigmas are bilobed and sessile; ovules are two per locule. Fruits are globose berries subtended by the persistent calyx. Floral morphology confirms placement of Neowawraea in tribe Phyllanthaeae, as suggested by the earlier study of wood anatomy.

EFFECTS OF VARIOUS NUTRIENT AND PHYTOHORMONE CONDITIONS ON THE GROWTH OF CYANOBACTERIA-FREE AZOLLA MEXICANA. Ethan M. Herschman and Robert W. Fisher, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Azolla ferns, freed of their nitrogen-fixing, cyanobacterial endosymbiont; *Anabaena azollae*, are morphologically abnormal and have a very slow growth rate. The purpose of this study was to improve the growth rate and morphology of the freed fern. Cultures were maintained on Murashige and Skoog salt medium (MS), alone or supplemented with the following: NAA, Kinetin, NAA and Kinetin, Thiamine, or i-Inositol. MS medium contains  $\text{NH}_4^+$  and  $\text{NO}_3^-$ , whereas standard cyanobacteria-free Azolla medium (I+) contains only  $\text{NO}_3^-$ . After a three week growth period biomass increase, shoot/root ratio, and chlorophyll concentration were measured. Biomass increase was decreased for ferns grown on MS, but increased for ferns grown on MS with NAA. Shoot/root ratios were all comparable to the intact system except those for ferns grown on I+. Slight variations in chlorophyll concentration were noted between all freed cultures, but no values were found comparable to the intact system.

CARPOPODIUM MORPHOLOGY AND TAXONOMY IN THE ASTERACEAE. Miles F. Johnson, Dept. of Biol., Virginia Commonwealth University, Richmond VA 23284-0001. The carpopodium from species of *Ageratum*, *Alomia*, *Eupatorium*, *Eupatoriadelphus*, *Conoclinium* and *Flesichmannia* is recorded with scanning electron microscope (SEM) photographs for the first time. The carpopodium is morphologically uniform in *Alomia* and *Eupatoriadelphus*, and with few exceptions, in *Ageratum*. It is variable in *Eupatorium* and *Fleischmannia*. The morphology of the carpopodium from *Conoclinium* agrees with the reports from earlier studies. The carpopodium can be a useful taxonomic tool in some genera. (Research supported by the Biology Department, Virginia Commonwealth University.)

AN EXPERIMENTAL GARDEN STUDY OF *HELENIMUM VIRGINICUM* BLAKE. John S. Knox,\*Dept. of Biol., Washington and Lee Univ., Lexington, Va. 24450. Taxonomic opinion differs as to whether *Helenium virginicum* Blake is distinct from *H. autumnale* L. As a first step toward resolving this dispute, an experimental garden comparison was undertaken to determine if the reported morphological and phenological differences between *H. virginicum* and *H. autumnale* L. var. *parviflorum* (Nutt.) Fern. are genetic or phenecotypic. Genetically based differences between these taxa were found in height, blooming period, cauline leaf morphology and abundance, pappus length, and length of basal leaves during flowering. The presence or absence of basal leaves during flowering was found not to be a good distinguishing character. Field observations suggest that *H. virginicum* and *H. autumnale* var. *parviflorum* are ecologically isolated.

COMPARISON OF MATURE AND SECOND-GROWTH WHITE PINE STANDS IN THE MID-APPALACHIANS. M. L. Lipford and H. S. Adams, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422. Quantitative data for vegetation and soils were compared from second-growth ( $49 \pm 2.2$  yrs) and mature ( $114 \pm 6.3$  yrs) white pine-dominated communities in Alleghany Co., VA and Greenbrier Co., WV, respectively. Pooled data from two 0.1 ha plots sampled at each locality revealed 46.5% similarity of canopy composition, but with only 5 of 18 taxa common to both communities. In the second-growth stands, white pine was the dominant canopy tree (IV = 71.8) followed by chestnut oak (IV = 12.0) and nine other species; in the mature stands, white pine was less important (IV = 37.3), sharing dominance with white oak (IV = 23.5), sugar maple (IV = 16.3) and nine other species. Density (N/ha) was greater in the younger stands (1,600) than in the mature stands (1,455), but basal area ( $m^2/ha$ ) in the mature stands (56.1) was almost twice that of the second growth stands (34.8). Bryophyte and herb cover values, and soil parameters (moisture, nutrients, organic matter, pH) were greater in the mature stands. Growth analysis of white pine tree cores ( $n = 15$ ) showed a strong release in the second-growth stands in the 1950s followed by reduction to values comparable to those of trees in the mature stands.

A COMPARISON OF SEASONAL DISTRIBUTION AND CONCENTRATION PATTERNS OF PHYTOPLANKTON SPECIES OVER THE CONTINENTAL SHELF OF THE U.S.A. H. G. Marshall, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, Va. 23508. Seasonal distribution and density maps are presented for ten ubiquitous diatoms from the northeastern continental shelf. Seasonal differences were noted among the species, but areas of major growth were characteristically associated with the coastal waters between Cape Cod and Cape Hatteras, Georges Bank, and the shelf region from Cape Cod seaward, and a shelf area north of Cape Hatteras. Supported by NOAA/NMFS Ocean Pulse Program.

SELECTED RARE PLANT SPECIES OF FAR WESTERN VIRGINIA. Douglas W. Ogle, Dept. of Biol., Va. Highlands Comnty. Coll., Abingdon, Va. 24210. Current population status, new localities, and potential threats are presented for the following species found in the southern Blue Ridge, Ridge and Valley, or Plateau regions of western Virginia. The selected rare species are: Abies Fraseri (Pursh) Poir, Campanula rotundifolia L., Euphorbia purpurea (Raf.) Fern., Galium boreale L., Lithospermum tuberosum Rugel, Paxistma canbyi Gray, Rhamnus lanceolata Pursh, Veronica scutellata L., Silene rotundifolia Nutt., and Vittaria.

ORDINATION OF MESIC FOREST COMMUNITIES IN SHENANDOAH NATIONAL PARK, VA. Oliver, Rick D. and W. Dean Cocking, Dept. of Biology, James Madison University, Harrisonburg, VA 22807. Sixty sites were sampled in a restricted randomized survey of northern Blue Ridge stands. Elevations ranged from 400 to 1100 m and a variety of slope exposures were sampled. Stands and species were ordinated by detrended correspondence analysis (DECORANA). The first axis was strongly correlated with successional age and therefore the data were partitioned into two stand Groups: late (greater than 60 years) and early (40-60 years) successional stands. Elevation was important in both groups, correlated with the initial axis in each. Slope exposure was correlated with second axis in the old stands, separating the southeast and northwest facing sides of the Blue Ridge. Soil characteristics (sand percentage and parent material) and soil temperature are related to elevation, particularly with the old stand ordination. Species composition is less consistent in the younger stands, while the old stands appear to be more organized, with oak species dominating.



SHORT TERM VARIATION IN COMPOSITION, ABUNDANCE AND BIOMASS OF PHYTOPLANKTON FROM THE ELIZABETH RIVER, VIRGINIA. Robert L. O'Reilly and H. G. Marshall, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, Va. 23508. Phytoplankton composition, biomass and associated variables were determined for four stations in the Elizabeth River, Va. Samples were obtained from each station, 2-3 times per day per week (October 15-December 1, 1984) to assess short term changes in phytoplankton composition, abundance (cells/l), biomass (chl a/l) and related phytoplankton variables (NO<sub>3</sub>; NH<sub>4</sub>; PO<sub>4</sub> and dissolved oxygen). An ultraplankton (<10  $\mu$ m) component was most abundant throughout the study ( $3 \times 10^6 - 7 \times 10^7$  cells/l); small-sized chain forming diatoms (e.g. Skeletonema costatum and Leptocylindrus minimus) cryptomonads, unidentified centric diatoms (<20  $\mu$ m) and blue-green cells (>10  $\mu$ m) were alternately abundant. Analysis of variance showed biomass (chl a) variability was mainly due to spatial (station to station) variability influenced by temporal (semi-daily; weekly) variation. Results from a Multiple Regression analysis indicated that station 4 (Eastern Branch) coupled with a slack tidal current accounts for 61% of the biomass variability. A cluster analysis was also run to identify associative patterns among phytoplankton composition and related variables.

THE EFFECT OF THE FUNGICIDE THIABENDAZOLE AND THE ANTIMYCOTIC NYSTATIN ON THE IN VITRO GROWTH OF CERATOCYSTIS ULMI USING VITAL STAIN TECHNIQUES. Santford V. Overton, R. Jay Stipes and J. D. Eisenback, VPI & SU, Blacksburg, VA 24061

Cultures of Ceratocystis ulmi grown on potato-dextrose agar, non-amended and amended with the fungicide thiabendazole and the antimycotic nystatin at varying concentrations (0.001, 0.01, 0.1, 1, 10, and 100  $\mu$ g/ml) were examined with the vital stains, triphenyl tetrazolium chloride, trypan blue, methylene blue and a mixture of 2% acid fuchsin in 70% ethanol, saturated chloral hydrate and 95% ethanol reported previously by McBryde (Am. J. Bot. 23:686-689, 1936). Inhibition of growth of C. ulmi into the agar was evident in cultures treated with 10  $\mu$ g/ml thiabendazole or 1  $\mu$ g/ml nystatin after 48 hours. Hyphae of C. ulmi in agar amended with thiabendazole or nystatin grew to an average depth of 1.14 mm or 0.72 mm, respectively, compared to 1.75 mm for the control. Increased hyphal branching was observed for each treatment. Surface inhibition of growth (pigmentation, colony diameter) was found at the lower concentrations of both compounds. Trypan blue and McBryde's stain gave consistently good results, while triphenyl tetrazolium chloride was unacceptable. Nystatin at lower concentrations was a more effective inhibitor of C. ulmi than thiabendazole, suggesting that the potential for control of the fungus may exist in vivo.

RARE PLANT MONITORING IN THE UNITED STATES. Mary E. Plamer, Research Botanist, National Model Heritage Program, The Nature Conservancy, Arlington, VA 22209. Monitoring is the acquisition of quantitative data that assess the performance of a population or community over time. Three types of monitoring are distinguished in a survey of 71 contacts, including all Heritage, Nature Conservancy and state programs with authority for plant protection in southeastern, northeastern and midwestern United States. General results and problem areas in methods and administration are discussed, and critical review of future projects in their planning stages is strongly recommended.

A PRELIMINARY STUDY OF THE VASCULAR FLORA OF BATH COUNTY, VIRGINIA. Cynthia A. Schroer and Norlyn L. Bodkin, Dept. of Biol., Harrisonburg, Va. 22807. Bath County is located in the northwest part of the state and covers 540 mi<sup>2</sup> (3.456 x 10<sup>6</sup> acres). It is in the Ridge and Valley Geographic Province of Virginia and is characterized by deep valleys, steep slopes, and narrow ridges dissected by a parallel drainage system. The minimum elevation is 336 m (1100 ft) and the higher mountain crests attain a maximum height of 1220 m (4000 ft). The county is primarily underlain by sedimentary rock. The higher ridges and slopes are sandstone and the lower elevations are shale. The extensive presence of shale in the county results in unique habitats for endemic shale barren species. The present study is a survey of the vascular flora of Bath County and attempts will be made to sample the major habitats as well as those areas capable of supporting unique taxa. Extensive floristic work has been done on the shale barrens, in this county, in the first half of the twentieth century. However, there are few records which authenticate the presence of many cosmopolitan species which are known to occur there. It is the goal of this study to document the existence of plants not currently listed as occurring in this county and to conduct a current and accurate review of the shale barren species.

RECENT RECOVERY EFFORTS WITH BETULA UBER, THE VIRGINIA ROUND-LEAF BIRCH.

Terry L. Sharik, Dept. of Biol., VPI & SU, Blacksburg, Va. 24061.

Of the 40 individuals known from the single wild population of the endangered Virginia round-leaf birch at the time of its rediscovery in 1975, only 11 remain. Recent attempts to increase the size of the population through controlled disturbances adjacent to seed trees have been severely hindered by vandalism, such that only 2 of 80 4-year-old seedlings remain. The Nature Conservancy recently acquired a 14 ha tract of private land adjacent to the population. This tract will be transferred to the U. S. Forest Service for protection and expansion of the population. Fifteen additional populations, each containing 96 seedlings originating from seed collected in the wild, have been established on public land adjacent to the natural population. Weaknesses in federal and state laws governing protection of endangered plants continue to thwart round-leaf birch recovery efforts.

OBSERVATIONS OF PHYTOPLANKTON COMPOSITION AND NUTRIENTS IN LAKE TRASHMORE, VIRGINIA BEACH, VIRGINIA. Seba B. Sheavly and H. G. Marshall, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, Va. 23508. Monthly phytoplankton collections and physical and nutrient data have been taken in a seasonal study (1985-1986) of Lake Trashmore. Spring phytoplankton concentrations are evenly distributed with a rather low diversity of species dominated by cyanobacteria, chlorophyceans, and cryptomonads. Diatoms were common, but not abundant, with dino-flagellates also in low concentrations. A pico-nanoplankton community (cells <5 µm) predominated and consisted of mainly cyanobacteria, chlorophyceans and unknown microflagellates. Phytoplankton composition from the other seasons are now under study. The annual nitrate and nitrite concentration minima occurred from late spring through fall, whereas phosphates and silicates were lowest during winter. However, ammonia concentrations fluctuated, with peaks in spring and early winter. Oxygen concentration patterns were similar throughout the water column with summer lows and winter highs. Compensation depths varied, but were greatest (2.2 m) in late spring and late summer, and shallowest (0.5 m) in late winter and early spring.

THE SARRACENIACEAE OF VIRGINIA. Phil Sheridan \*, Meadow Creek Pond, Rt. 2 Box 310H Woodford, Va. 22580. Over a two year period the current and historical range of Sarracenia flava and S. purpurea was analyzed for the state of Virginia. Data was compiled based on fieldwork, herbarium and bibliographic search and personal interviews. Populations were examined for phenetic variation and habitat preference. The status of the taxon was also assessed. S. flava was found to have occurred in eight counties with a total of seventeen populations. Three sites were relocated in three counties and two new stations are reported for Dinwiddie Co. S. purpurea ranged over 14 counties with 19 populations. Three historical stations were found in three counties with four new colonies in Sussex and one each in Caroline and Dinwiddie counties. S. flava was found to have two color variants. One form is reported with pure green leaves and the other with moderate purple veining. S. purpurea was found to have a wide range in the size of the pitchers with deep purple venation of full sun plants. Ideal habitat for both species was observed to be a springhead. Recommended status for both species is threatened in Virginia.

SEASONAL PHYTOPLANKTON PATTERNS WITHIN THE NANSEMOND RIVER, VIRGINIA. Cindy E. Shomers and H. G. Marshall, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, Va. 23508. A twelve month study of phytoplankton composition at two stations in the Nansemond River indicated a pico-nanoplankton assemblage of cells (1-10  $\mu$ m) accounted for 80-90% of the total cell counts. The assemblage, composed of cyanobacteria and chlorophyceans, had peak concentrations in the spring. The phytoplankton >10  $\mu$ m demonstrated two peak concentrations; the largest in spring and the other in fall. These were primarily composed of diatoms, dinoflagellates and cryptomonads. Predominant species at both stations included Skeletonema costatum, Cylindrotheca closterium and Heterocapsa triquetra. Gymnodinium sp., Cryptomonas sp. and Pyramimonas sp. were also abundant. Cell concentrations were generally higher at the station closest to the mouth of the river. Both of the phytoplankton assemblages demonstrated inverse growth peaks to the lowest salinity levels in spring; however, the fall concentration of ultraplankton peaked while the salinity was still fairly high. It is probable that increased runoff lowered salinity and simultaneously caused nutrient enrichment thereby stimulating the spring growth.

THE EFFECTS OF LIGHT AND PHOSPHORUS LIMITATION ON THE GROWTH AND PHYSIOLOGY OF Chlorella pyrenoidosa. F. P. Silverman, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284, & B. H. Rosen\*, Sch. of Biol. Sci., Univ. of Nebr., Lincoln, Nebr. 68588. Chlorella pyrenoidosa (UTEX 1230) was subjected to nutrient limitation and light stress in batch cultures at 2 irradiances in complete (P+) or phosphorus free (P-) medium. Cultures were sampled at 12 hour intervals for 48 hours for cell density, Chl a levels, fluorescence capacity, and oxygen evolution. Cell density was lower in low light (LL) and P- cultures compared to the high light (HL) and P+ counterpart cultures. In the cultures, Chl a was higher in the HL and P+ cultures during the first 36 hours, but due to self shading in these cultures, the levels of Chl a were higher in the corresponding P- and LL cultures after 36 hours. Fluorescence capacity and oxygen production measures were greater in the P+ cultures than in the P- cultures. Those cultures grown at HL in P- medium showed lower levels of fluorescence capacity and oxygen evolution than those cultures grown at the LL irradiance. This indicated an additive physiological response to high light and low nutrient stress. (Supported by the Grants-in-Aid Program for Faculty of Va. Commonwealth Univ. to BHR.)

AN ECOLOGICAL STUDY OF SUBALPINE SPRUCE-FIR FORESTS IN THE SWAN MOUNTAINS OF NORTHWESTERN MONTANA. S. L. Stephenson, Dept. of Biology, Fairmont State Col., Fairmont, WV 26554 and H. S. Adams, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422. Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) are the most characteristic species of high-elevation forests in the Rocky Mountains of the western United States. During the 1985 field season, increment growth cores were collected from both species in several representative stands of this forest type located at elevations of 1830 to 2050 m in the Swan Mountains of northwestern Montana. In addition, quantitative data were obtained for composition and structure of the vegetation and for chemical and physical characteristics of soils associated with each study site. Mean ages  $\pm$  SE of cored trees were  $220 \pm 13.3$  yrs for Engelmann spruce and  $132 \pm 8.5$  yrs for subalpine fir. Dendroecological (tree-ring) analysis showed no evidence of a growth-trend decline of the type observed for comparable species in subalpine spruce-fir forests of eastern North America. Both Engelmann spruce and subalpine fir displayed similar patterns of growth for the period of 1800-1984. Average growth rates for the entire period were 1.19 mm/yr for Engelmann spruce and 0.97 mm/yr for subalpine fir.

COMPARATIVE GROWTH RESPONSE OF FUNGI CULTURED ON AGAR MEDIA STERILIZED BY THE AUTOCLAVE OR MICROWAVE OVEN. R. Jay Stipes, Jean L. Ratliff and Ramon Cu, Dept. Plant Pathol., Physiol. & Weed Sci., Virginia Tech, Blacksburg, VA 24061.

The autoclave has long been the conventional tool for the preparation of microbiological agar media, but the advent of microwave oven technology offers a potential alternative to it; the microwave is faster and precludes lab heat-up. We compared the sterility of, and effects on growth of three fungi (*Cryphonectria parasitica*, *Endothia gyrosa* and *Glomerella cingulata*) on, media prepared by both methods, since the sources and intensities of heat differ for the microwave (electromagnetic waves, 1,000 - 300,000 MHz) and autoclave (steam). Commercial agars (BBL potato-dextrose and Difco cornmeal), and glucose-yeast extract agar, were prepared by autoclaving from 10 - 120 min. or by microwaving 3 - 15 min. The linear growth of all fungi, measured after 5 days incubation at 25 C, was similar within all individual media autoclaved or within all individual media microwaved; growth, however, was less by values up to 40% on microwaved media. Commercially prepared media were generally free of bacterial contamination when prepared by both methods, whereas the glucose-yeast extract was not when microwaved. Microwaving, therefore, can be used to prepare media with discretion after adequate experience with one's specific needs.

APPLE FRUIT LESION DEVELOPMENT INDUCED BY SPECIES OF THE ENDOTHIA/CRYPHONECTRIA COMPLEX AS IT RELATES TO THEIR TAXONOMIC RELATIONSHIPS. R. Jay Stipes, Jean L. Ratliff and Jessie A. Micales, Dept. Plant Pathol., Physiol. & Weed Sci., Virginia Tech, Blacksburg 24061.

Apple fruit lesion development has been used recently to differentiate virulent and hypovirulent strains of *Cryphonectria parasitica* (= *Endothia parasitica* sensu antiquo), the chestnut blight fungus (Fulbright, Phytopathology 74:722-724). Since strong evidence has been accumulated to document the separation of *Endothia* spp. sensu priori, into the genera *Endothia* and *Cryphonectria* (Barr, 1978; Micales, 1985), we assayed the potential of 7 isolates each of *E. gyrosa* and *C. parasitica*, to induce lesion development in 'Yellow Delicious' and 'Red Delicious' apple fruits. Mycelial plugs (6 mm) were placed into identical wounds of healthy apple fruits and incubated at 25C for 3 wks. Highly significant differences in lesion development in both apple cultivars were induced by the two species. Average lesion diameters on 'Red Delicious' were 7.9 and 70.1 mm for *E. gyrosa* and *C. parasitica*, respectively; while those on 'Yellow Delicious' were 17.7 and 102.7 mm, respectively. These findings further confirm the separation of the taxa, using their pathological properties in non-woody host tissues.

COMPARISON OF VERTICAL PHYTOPLANKTON CONCENTRATIONS AND CELL VOLUMES AT THE SHELF BREAK. Bruce B. Wagoner and H. G. Marshall, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, Va. 23508. Six stations along the outer margin of the U.S. northeastern continental shelf were sampled in April 1984 from surface to 150 meters. Total cell concentrations and volumes were tested for variation by station and depth using analysis of variance. In all cases a relatively homogeneous pattern was found for all groups at each depth and station, with none of the stations showing a higher concentration than the others. There was an indicated variation in phytoplankton volume and concentrations between the upper depths sampled, while in only one instance was there any significant difference between the bottom depths. A homogeneous pattern of distribution was not found for or within any group at each station. Predominant species included Gymnodinium sp. and Gyrodinium sp. throughout the water column at all the stations; with small chain forming diatoms at the surface to larger Coscinodiscus wailesii at the lower depths. Pico-nanoplankton cells (<5  $\mu$ m) were not in high concentrations. Supported by NOAA/NOS.

HERB AND SHRUB LAYERS IN ORDINATION OF MESIC FOREST COMMUNITIES IN SHENANDOAH NATIONAL PARK, VA. Ward, Deanna M. and W. Dean Cocking. Dept. of Biology, James Madison Univ., Harrisonburg, VA 22807. Herb and shrub layer species cover estimates within 60 mesic forest communities, were compared to each other on the basis of similarity and used to construct a DECORANA ordination of the stands. The herb ordination for all stands was segregated by successional age on the first axis. Two separate ordinations were constructed using only the old age stands in one and the young stands (40-60 yrs.) the other. Elevation emerged as the predominant x axis correlate for both age classes. Because of geologic layering, distribution on the Pedlar and Catoctin soil parent materials separate on the x axis and many herb and shrub species were strongly associated with each type. Herbs growing on the more fertile and less acidic Catoctin soils include: Laportea canadensis, Trillium grandiflorum, and Cypripedium calceolus. Kalmia latifolia, Vaccinium spp., and Rhododendron spp. were associated with the less fertile and more acidic Pedlar soils.

PRELIMINARY DEMOGRAPHIC STUDIES OF THE SMALL WHORLED POGONIA, ISOTRIA MEDEOLOIDES (PURSH) RAF., IN VA. Donna M. E. Ware, Dept. of Biol., Col. of William & Mary, Williamsburg, Va. 23185. Isotria medeoloides, a native, terrestrial orchid, is listed as endangered federally, and in Virginia, where it occurs at Chisel Run (C-1), Ft. A.P. Hill (C-2), and Prince William Forest Park (C-3), in James City, Caroline, and Prince William counties, respectively. It grows in open, upland, mixed-hardwoods typical of the region. C-1 and C-2 have been monitored by Ware in '84, '85, & '86, and C-3 by Gene Cooley of the NPS. C-1, the largest colony S. of New England, had 127 plants in '85; C-2, 22; and C-3, 10. C-1 has a preponderance of vegetative plants [89 (69%) in '85], in contrast to 4 (18%) in C-2, which may indicate a significantly higher level of reproduction in C-1. Twenty-five percent (3 yr. av.) of the plants in C-1 flowered; 56% (2 yr. av.) in C-2. Five plants in C-1 flowered 3 successive yrs. Thirteen plants passed from flowering status to vegetative status and 9 the reverse. Five of these plants changed status twice. Of 11 plants in C-1 that set fruit in '85, 4 survived to disperse. Plants producing a flower nub (aborted flower) one year may be vegetative, produce another nub, or flower the next year. Progression from flowering status to vegetative status indicates that the nub stage is not simply a progressive stage of initial maturation of a plant to reproductive status.

DECORANA ORDINATION OF THE ORIGINAL SOUTHERN MIXED HARDWOOD FOREST. Stewart Ware, Dept. of Biol., Coll. of William & Mary, Williamsburg, VA, 23185. When E. Quarterman and C. Keever published their original study of the Southern Mixed Hardwood Forest in 1962, modern computer-generated ordination programs were not available. They have generously made their original data available to me for such ordination. The high importance of the successional loblolly pine in stands of theirs which are otherwise vegetationally quite dissimilar causes distortions in either polar or detrended correspondence ordinations. By modification of the input matrix I have been able to generate a DECORANA (detrended correspondence analysis) ordination which essentially ignores the abundance of pine. In this ordination the evergreen laurel oak (Quercus hemisphaerica) largely dissociates itself from beech, white oak, and to some extent even magnolia, and is most abundant in sandy, nutrient-poor soils. Peaks of distribution of spruce pine (Pinus glabra), magnolia, white oak, mockernut hickory, southern red oak, and post oak are arranged in that order along a presumed moisture gradient from moist to dry, while beech overlapped all of these but centered between magnolia and white oak. Sweetgum and pignut hickory overlapped distributions of both laurel oak and beech and white oak, so that despite the dissociation of laurel oak and beech no vegetational boundaries are apparent.

THE DISTRIBUTION AND STATUS OF ARABIS SEROTINA, A SHALE BARREN ENDEMIC. Thomas F. Wieboldt, Herbarium, Dept. of Biology, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. Arabis serotina Steele (Brassicaceae) is a species endemic to shale barrens of the Ridge and Valley Province of Virginia and West Virginia. It has, until recently, been confused with the morphologically similar Arabis laevigata (Muhl.) Poir. var. burkii Porter, a more wide-ranging plant of greater ecological amplitude. Arabis serotina flowers in July and August whereas Arabis laevigata var. burkii flowers in April and May, similar to the typical variety. The smaller flowers and diffuse inflorescences of A. serotina are shown to clearly distinguish it and to correlate well with the late flowering period. The geographical distributions are compared and the habitat preferences more clearly described. A. serotina is shown to be a strict shale barren endemic. It is extremely rare, presently being known from only 24 sites, 12 in Virginia and 12 in West Virginia. By contrast, A. laevigata var. burkii appears to be frequent northward but incidentally rare in Virginia by virtue of its being at the periphery of its range here.

THE DISTRIBUTION AND STATUS OF CARDAMINE LONGII. Thomas F. Wieboldt, Herbarium, Dept. of Biology, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. Cardamine longii Fernald (Brassicaceae) was described by M.L. Fernald from coastal Maine and subsequently found in the estuaries of the Chesapeake Bay where it was thought to be a rarity of fresh tidal shores. Finding that specimens of this plant were passing as C. pensylvanica Muhl. var. brittoniana Farwell led to a number of new records expanding the known range to the Southeastern U.S. Atlantic and Gulf Coastal Plains. It is also shown to occupy a much wider variety of habitats. Fieldwork showed that C. longii is considerably more variable than described and commonly occupies swamp forest habitats in Virginia. The plant is shown to be well adapted to riverine habitats by its apetalous, self-pollinating flowers, lax and easily fragmenting stems which readily root at the nodes, and reduced inflorescences with short pedicelled fruits. Speculation by others that C. longii might be an intertidal form of C. pensylvanica led to transplant studies. Progeny grown from seed in a terrestrial environment produced strictly erect stems and a variety of reduced-to-normal flowers. Silique length held true as did the short pedicel character. A chromosome count of  $2n = 16$  is reported and a brief morphological comparison is made between several closely related taxa.

## Chemistry

INITIAL STUDIES LEADING TO THE SYNTHESIS OF THERMALLY STABLE POLYPYRAZOLINONES. Stephen M. Andrews, and R.G. Bass, Department of Chemistry, Virginia Commonwealth University, Richmond, VA 23284 and P.M. Hergenrother, NASA Langley Research Center, Hampton, VA 23665. As part of an effort to synthesize high performance/high temperature polymers for functional and structural applications, the reaction of aromatic bis(propynoic esters) with aromatic dihydrazines is under investigation. Prior to the synthesis of polymers a series of model compound pyrazolones have been prepared in order to demonstrate the feasibility of the pyrazolone forming reaction. An aromatic dihydrazine has been reacted in a 1:2 molar ratio with ethyl phenylpropiolate to yield a series of aromatic bis(pyrazolones) in near quantitative yield. Spectral data (IR,  $^1\text{H}$  and  $^{13}\text{C}$  NMR) has been obtained to confirm the structure of products. A preliminary series of polypyrazolones have been prepared in good yields. Spectral data for the polymers is consistent with data obtained from model compounds. The polymers exhibited inherent viscosities up to 0.44 dL/g and several formed creasable thin films. This research was performed under NASA Langley Research Center Grant NAG 1-239.

COMPUTER-ASSISTED ANALYSIS AND INTERPRETATION OF EPR SPECTRA. S. Brad Arington and Herbert J. Sipe, Jr., Department of Chemistry, Hampden-Sydney College, Hampden-Sydney, VA 23943.

Our previously reported FORTRAN programs, which simulate EPR spectra by Fourier transform procedures and analyze them by autocorrelation techniques, have been converted to the FORTH-based ASYST language (Macmillan Software Company). In newly created programs, we have developed procedures to vary the EPR parameters systematically about the autocorrelation estimates and to seek an optimum set of parameters by minimizing a "residual" function. We discuss the nature of the residual function surface, an algorithm for locating its absolute minimum, and an algorithm for refining the EPR parameter estimates in the vicinity of the minimum residual. This set of programs can handle EPR spectra with up to 10 hyperfine coupling constants, five of which may be varied at any given time in the residual minimization procedure. Results of applying these procedures to synthetic spectra are reported as are difficulties encountered with application to experimental spectra.

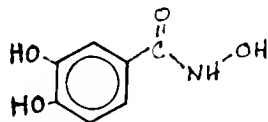
CONDITIONS UNDER WHICH THE FORMATION OF CIS-2,5-DI-t-BUTYLBENZOQUINONE DIEPOXIDE IS FAVORED. Carol L. Belote\* and Elizabeth M. Hairfield, Mary Baldwin College, Staunton, Va. 24401. Benzoquinone epoxides have been under examination for some time because they occur as metabolic intermediates and have potential as anti-cancer agents. Furthermore, benzoquinone diepoxides exist in two isomeric forms, cis and trans. Interest at Mary Baldwin Col. has focused on the diepoxides of 2,5-di-t-butylbenzoquinone. Previous work has shown that the base catalyzed epoxidation is first order each in benzoquinone, peroxide, and base, and that frequently the formation of the cis diepoxide is favored. Does this stereospecificity arise from the dielectric constant of the solvent (more cis is formed in anhydrous alcohol than in alcoholic dioxane); or does it arise from the bulk of the oxidant (more cis is formed in the presence of t-butylhydroperoxide than hydrogen peroxide); or does it arise from the nature of the base (more cis is formed with NaOH than with Triton B)? Our work is directed toward answering these questions.

Substituted cis benzoquinone diepoxides are chiral. It is hoped that through understanding the mechanism by which the cis is favored, methods can be developed for controlling not only the geometric stereoisomerism but the optical isomerism as well.

REACTIONS OF DIDOX (3,4-DIHYDROXYBENZOHYDROXAMIC ACID), A POTENTIAL CANCER CHEMOTHERAPY DRUG, NEAR PHYSIOLOGICAL pH. David Brown and George C. Grant, Dept. of Chemical Sciences, Old Dominion University, Norfolk, VA 23508.

DIDOX has been shown to inhibit tumor growth in mice and inhibits the enzyme ribonucleotide reductase.

We investigated the degradation of DIDOX near physiological conditions at room temperature and 8, 50, and 75 degrees Celcius. Analyses were



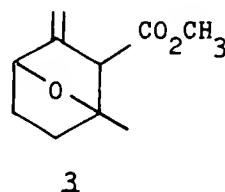
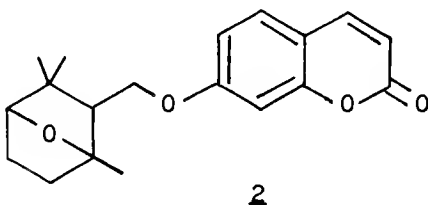
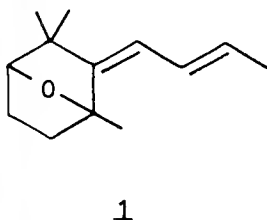
performed with a Spectraphysics 8700 Ternary Gradient HPLC and a UV detector using a C18 column with an isocratic 90 % methanol/10 % formic acid mobile phase. At 50 and 75 degrees the decomposition followed first order kinetics and increased as the pH was raised from 6.4 to 8.0 (Goods buffers BES and MES). Three degradation products were detected by their appearance in the chromatograms over time, but they have not been identified. The influence of the potential preservatives benzyl alcohol, ascorbic acid, p-hydroxybenzoic acid and sodium bisulfite was also studied.

AN INVESTIGATION OF THE SYNTHESIS AND CHARACTERIZATION OF LINEAR SUGAR-PHOSPHATE POLYMERS AND THE ORIGIN OF NUCLEIC ACIDS. John R. Carder, Stanley Hall, John D. McCaffery, James K. Shillington, Michael A. Pleva, Dept. of Chemistry, Washington and Lee Univ., Lexington, Va. 24450. While the current nucleotide theory states that nucleotides evolved and were bonded together by prebiotic condensing agents into RNA and DNA, it is possible that an alternate mechanism for nucleic acid synthesis exists. An alternate mechanism, obviously in sharp contrast to the accepted theory, may exist whereby in the formation of nucleic acids, a sugar-phosphate chain evolved first, and the purine and pyrimide bases may have been added after the formation of the sugar-phosphate chain. To prove this alternate theory, we must first synthesize a linear sugar-phosphate polymer, construct reference standards, and characterize it according to molecular weight, length and linearity. A linear sugar-phosphate chain has been synthesized and initial characterization indicates that the polymer is approximately the same length and size of the sugar-phosphate chains found in nucleic acids.

ANOMALOUS REACTIONS IN THE NENITZESCU 5-HYDROXYINDOLE SYNTHESIS (STUDIES ON THE NENITZESCU SYNTHESIS OF 5-HYDROXYINDOLES. IV.) Donna M. Cason\* and James B. Patrick, John Baker Daffin Department of Chemistry, Mary Baldwin College, Staunton, Virginia 24401. The reaction of 2,5-dihydroxybenzoquinone with methyl 3-aminocrotonate in several solvents does not yield the expected 4,5,7-trihydroxyindole derivative. Instead, a red water-soluble, infusible product is obtained which we postulate to be the bimolecular face-to-face electron transfer complex proposed by us as a key intermediate of the Nenitzescu Synthesis in earlier papers presented to This Academy. In this case we believe that the complex is prevented from dissociation, and hence from completing the reaction, by strong hydrogen bonding between its two components. We now report a variety of chemical and spectral studies of this product. The results of our studies all seem to be consistent with the proposed structure but are insufficient for a definitive proof.



SYNTHESIS OF MONOTERPENE NATURAL PRODUCTS: APPROACHES TO 2,5-EPOXYMEGASTIGMA-6,8-DIENE AND 3',6'-EPOXYCYCLOAURAPTEN. Michael P. DiFazio, William A. Wallace, & Albert T. Sneden, Dept. of Chemistry, Virginia Commonwealth Univ., Richmond, VA 23284. The oxabicyclo[2.2.1]heptane nucleus common to 2,5-epoxymegastigma-6,8-diene **1** and 3',6'-epoxycycloaurapten **2** was accomplished via a Diels-Alder reaction between 2-methylfuran and maleic anhydride. Hydrogenation followed by regioselective reduction afforded the more sterically hindered lactone. Opening the lactone moiety with lithium thiomethoxide followed by oxidation and thermal elimination provides the nonconjugated ene-ester derivative **3**. The conversion of **3** into precursors of **1** and **2** will be discussed.



Mo(VI) PEROXO COMPLEXES WITH IMIDAZOL. C. Djordjevic and J. L. Gunderson.\* Dept. of Chem., Col. of William and Mary, Williamsburg, Va 23185. Imidazol is an important molecule, involved in the bonding with metal ions in living matter, and investigated in a number of model compounds for biochemistry. We are now investigating Mo(VI) and V(V) peroxo systems with imidazol and have prepared the first peroxo-imidazol ligand combination observed so far. A crystalline complex of the formula  $\text{MoO}(\text{O}_2)_2\text{Im}(\text{H}_2\text{O})$  was obtained, which is a stable yellow compound. It is soluble in water, where peroxo  $\longrightarrow$  metal charge transfer band occurs at 315 nm (shifted only slightly in comparison with the solid state spectrum). The IR spectra reveal distinct strong bands at  $960\text{ cm}^{-1}$  and  $860\text{ cm}^{-1}$ , assigned to  $\text{Mo}=\text{O}$  and  $\text{O}-\text{O}$  stretchings, respectively. V(V) does not form analogous compounds, and further investigations are in progress.

PEROXO COMPLEXES OF V(V) AND Mo(VI) WITH NICOTINIC ACID. C. Djordjevic and S. J. Sheffield, Dept. of Chem., Col. of William and Mary, Williamsburg, Va. 23185. Peroxo complexes of these two metal ions containing heteroligands occurring in living matter are of special interest to metallobiochemistry. The peroxo complexes with nicotinic acid, which we have recently prepared, are fine crystalline compounds of the formula  $\text{K}[\text{VO}(\text{O}_2)_2(\text{NAH})](\text{H}_2\text{O})$ ,  $\text{MoO}(\text{O}_2)_2(\text{NAH})(\text{H}_2\text{O})$  and  $\text{M}^1[\text{MoO}(\text{O}_2)_2\text{NA}]\text{H}_2\text{O}$ , where  $\text{NAH} \equiv \text{C}_6\text{H}_5\text{NO}_2$ ,  $\text{M}^1 = \text{K}, \text{NH}_4$ . They are stable in air and represent the first peroxo-nicotinic acid ligand combination reported so far. The complexes are soluble in water, where the cyclic voltammograms display two and three reduction peaks for vanadium and molybdenum, respectively. The charge transfer bands in aqueous solutions and in the solid state are found in UV/V spectra in the region of  $350\text{ cm}^{-1}$ . According to the IR spectra, the presence of a coordinated carboxylato group is indicated, and the strong bands due to  $\text{M}=\text{O}$  and coordinated  $\text{O}-\text{O}$  stretchings appear in the region around  $950$  and  $870\text{ cm}^{-1}$ , respectively. Further investigations are in progress.

INFLUENCE ON REGIOSELECTIVITY BY LEWIS ACIDS IN DIELS-ALDER REACTIONS OF ACROLEIN. Osman F. Guner, R. M. Ottenbrite, *Dept. of Chem., Va. Commonwealth Univ., Richmond, Va. 23284.* & P. V. Alston, *duPont Textile Fibers Dept., Kinston, North Carolina, 28501.* The geometries of acrolein and borontrifluoride complexed with acrolein are optimized using minimum basis STO-3G method. The optimized geometries are then used in STO-6G, STP-6G, 4-31G and 6-31G calculations. The frontier molecular orbital energies and coefficients obtained from these *ab initio* calculations are used to explain the role of Lewis acid catalysis in Diels Alder reactions. The significance of "Secondary Orbital Interactions" involvement in establishing regio- and stereoselectivity in the catalyzed reactions is highlighted. The thermal and catalyzed Diels Alder reactions of acrolein with two selected dienes are carried out. The Diels Alder adducts are identified and shown to be complementary to the theoretical calculations. Interesting low temperature epimerizations are observed. It is also shown that epimerizations proceed much faster with the effect of Lewis acid catalysis. The dependance of the product distribution to the temperature is established.

OPTIMIZED SLATER-TRANSFORM-PREUSS MINIMUM BASIS SETS FOR SELECTED SMALL MOLECULES. O. F. Guner, D. D. Shillady, B. K. Rao, *Dept.s of Chemistry and Physics, Va. Commonwealth Univ., Richmond, Va. 23284.* Pair-excitation multiconfigurational self-consistent field (PEMSCF) treatment of eleven small molecules ( $\text{LiH}$ ,  $\text{BeH}_2$ ,  $\text{BH}_3$ ,  $\text{BF}$ ,  $\text{CH}_4$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_2$ ,  $\text{CH}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{O}$  and  $\text{HF}$ ) has been carried out in a minimum basis set of Slater-Transform-Preuss functions as fitted by six gaussians (STP-6G). The advantages of accuracy without using a split basis are shown by comparison to familiar 4-31G and 6-31G calculations using molecular geometries optimized with STO-6G basis sets. An  $\text{N}^5$ -type AO-to-MO step is used only for the active-space for pair-excitations, with the remainder of the generalized Fock matrix constructed in the atomic orbital representation followed by a unitary transformation to the molecular orbital representation. A typical time for (SCF + 20 iterations MCSCF [9 X 9] + natural orbital analysis) treatment of ethylene was 78 seconds on an IBM-3081D. Fully optimized STP parameters are given and appear to be transferable as shown for acrolein and acrolein complexed  $\text{BF}_3$ .

CAFFEINE: A PASSING STIMULANT. D. Shawn Harvey, Michael S. Blackwood, Mark H. Whiteford, M. Christopher Talley, Michael A. Pleva, James K. Shillington, *Dept. of Chemistry, Washington and Lee University, Lexington, Va. 24450.* Over the past few years, society has grown increasingly aware of potentially harmful, though common, substances. For example, excessive caffeine consumption increases the risk of heart disease. As a result of this growing concern, we initiated a new project designed to measure caffeine consumption within the Washington and Lee community. Our methods were straightforward: upon collecting a urine sample, the caffeine analyte was extracted using Baker extraction columns. A Hewlett-Packard gas chromatograph quantitatively measured the amount of caffeine in the resulting eluent. Currently, our research indicates that caffeine consumption may climb to 500% normal consumption during periods of stress (e.g. Organic exams, P-Chem test, etc.).

EFFECTS OF ELECTRON BOMBARDMENT ON POLYARYLENE ETHERS. K. B. Kingsbury\*, D. S. Hawkins\*, R. L. Kiefer, and R. A. Orwoll, *Dept. of Chem., Col. of William and Mary, Williamsburg, Va. 23185,* and G. F. Sykes, Jr\*, *NASA Langley Research Ctr., Hampton, Va. 23665.* Two novel polyarylene ethers were subjected to irradiation by high energy (70-85 keV) electrons. Films of these two polymers received doses between 0 and 35 MRads. The effects on the chemical structure of the polymers were studied by measuring changes in the solution viscosity and in the amount of soluble material and by monitoring with a mass spectrometer the gaseous products evolved during irradiation. Scission and crosslinking yields were estimated. (Supported by NASA Research Grant No. NAG-1-593.)

DECOMPOSITION REACTIONS OF TETRALIN AT 450°. Gregory Lacy, Wayne M. Stalick, and George W. Mushrush, Department of Chemistry, George Mason University, Fairfax, VA 22030.

Recent studies of the thermal decomposition of tetralin have been unable to determine the mechanism of this thermolysis. This paper details the results of a study of tetralin pyrolysis in sealed stainless steel reactor tubes at 450°C. The reactions were run from time periods of 15 minutes to 5 hours. By investigating the reaction at both short and long time periods, complexities arising from significant secondary reactions of the primary products were reduced. The product mixtures were analyzed by combined capillary column GS/MS. The major observed product was naphthalene. Minor products included substituted benzenes, methyl indan and decalin. The complete product distribution and a mechanism consistent with the observed results will be presented.

THE INTERACTIONS OF THE VARIOUS COMPONENTS OF ACID PRECIPITATION WITH STRUCTURAL METALS. Jeffrey S. Mandak, Joseph G. Whelan, Brian Haggerty, Michael A. Pleva, James K. Shillington, Dept. of Chemistry, Washington and Lee Univ., Lexington, Va. 24450. The Rockbridge County area is subjected to precipitation of relatively low pH and it was hypothesized that this condition has a significant effect on structural metals, namely steel, copper, aluminum, and anti-rust painted steel. The initial phase of the experimental entailed the ongoing monitoring of precipitation in the area to determine the average acidity and sulfate concentration of the precipitation. Next, the metals were exposed to simulated natural conditions for varying periods to ascertain the nature of the possible interactions between these components of the acid precipitation and the corrosion of metals.

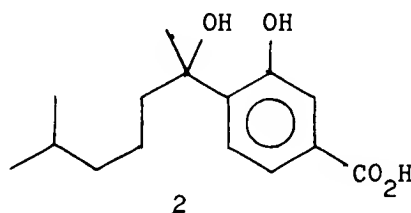
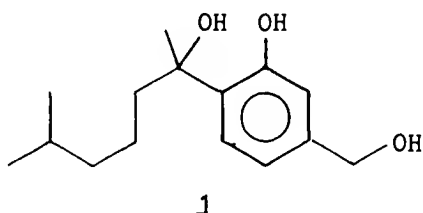
STERIC EFFECTS IN THE HALOGENATION OF DIISOPROPYLAMINE-BORANE  
Leland D. Melvin and William H. Myers, Dept. of Chemistry,  
University of Richmond, Richmond, Virginia 23173

Borane adducts of diisopropylamine were halogenated using either free halogens or halogen halides, and the proton NMR spectra of these amine-haloboranes were obtained. The NMR patterns initially showed downfield shifts in the methyl and methine proton resonances with increased size of halogen or with increased number of halogens on boron. In the case of chlorination six sets of doublets were observed, for the methyl protons, including starting material as one of the six. Assignment of structure for these six resonances will be made, and behavior of the corresponding bromine and iodine systems will be discussed as well. Correlation of these observations with steric factors in the structure will be made.

THE SYNTHESIS OF 1-BROMO-2-ETHOXYETHENE FROM ETHYL VINYL ETHER. Wayne M. Stalick, Department of Chemistry, George Mason University, Fairfax, VA. 22030  
1,2-Dibromoethoxyethane was treated with a number of basic reagents, mainly tertiary amines, to accomplish dehydrobromination to 1-bromo-2-ethoxyethene, a precursor to an acetaldehyde carbanion equivalent. The yield of this vinyl bromide and the other common by-products of reaction varied markedly depending on the base and reaction conditions employed. Direct distillation of the product under reduced pressure from a tertiary amine solution was the method of choice, showing little if any effect of temperature and giving reproducible results. Following this procedure, N,N-dimethyldodecylamine was the preferred base for this reaction. The results of the dehydrobromination reaction using a combination of more than 30 different bases and conditions will be presented.

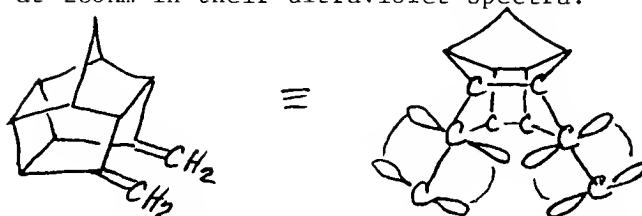
THE USE OF ATOMIC SPECTROMETRY AS A METHOD OF DETECTION OF ION CHROMATOGRAPHIC EFFLUENTS. I.T. Urasa, Dept. of Chemistry, Hampton Univ., Hampton, Va. 23668  
The features that make ion chromatography an attractive analytical technique include its ability to separate and quantitate organic and inorganic anions and cations; the relatively simple chromatographic peaks obtainable; and the possibility of using a wide range of detector systems thus facilitating the enhancement of measurement sensitivity and selectivity. The use of d.c. plasma atomic emission spectrometry (DCPAES) appears to be a suitable method of detection for ion chromatography. Using this kind of detector allows element selective measurements, thus avoiding interference and other problems that may arise from the presence of different chemical species in solution. Since DCPAES measurements are based on the atomic emission of the element of interest, all forms of that element can be measured with identical sensitivity, precision, and detection limit.

SYNTHESIS OF FUNGAL METABOLITES: SYDONOL AND SYDONIC ACID. William A. Wallace & Albert T. Sneden, Dept. of Chemistry, Virginia Commonwealth Univ., Richmond, VA 23284. The synthesis of the fungal metabolites sydonol **1** and sydonic acid **2** from 4-methylsalicylic acid using two slightly different routes has been investigated. The routes to **1** employ, in different order, the introduction of the alkyl side chain via a Grignard reaction using 1-bromo-4-methylpentane, bromination of the 4-methyl group on the aromatic nucleus by free radical bromination, and hydrolysis of the bromide to provide the benzylic hydroxyl moiety. Conversion of **1** into **2** will be accomplished by oxidation of the benzylic hydroxyl group.



INTERACTION OF ISOLATED DIENES IN A CAGE STRUCTURE. George Whitney, Dept. of Chemistry, Washington & Lee Univ., Lexington, VA, 24450.

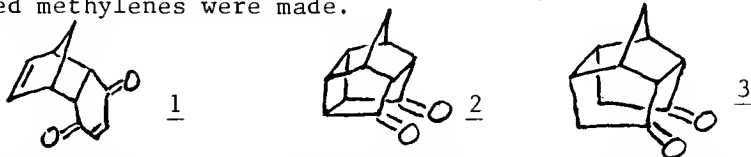
Isolated dienes shouldn't interact at all. But, where they are separated by two sets of two sp<sup>3</sup> carbons, yet forced into a position in which their pi orbitals must share space, they do. And these interactions are seen as small absorptions at 280nm in their ultraviolet spectra.



This cage dimethylene is a difficultly isolable compound. With oxygen, or heat, it's easily transformed into a polymer. However, several serious attempts to cyclize the double bonds to cyclobutane by radiation were made. Prolonged treatment by ultraviolet with and without catalysts and initiators produced no [2.2.2.0]propellane, but only "delicate" starting diene, intact!

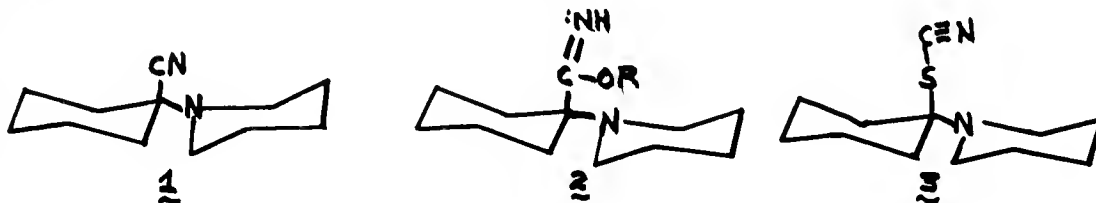
WITTIG REACTIONS WITH A CAGE DIKETONE. George S. Whitney and James Sperka\*, Dept. of Chemistry, Washington & Lee Univ., Lexington, VA, 24450.

The well-known cage diketone pentacyclo[6.2.1.0<sup>2,7</sup>.0<sup>4,10</sup>.0<sup>5,9</sup>]undecane-3,6-dione 2, can be made by irradiating the Diels-Alder adduct 1 of cyclopentadiene and quinone. To form the cage, the endo double bond cyclizes with the far double bond into a cyclobutane. In trying to replace the carbonyl oxygens with methylenes, we found that the usual Wittig process will fail. Higher temperatures are needed, and that means changing the ether solvent to dimethyl sulfoxide, and using, as base,  $\text{Na}+\text{CH}_3\text{SOCH}_2^-$ . Both single and di-substituted methylenes were made.



The diketone can also be reduced, although, unusually, the single carbon-carbon bonds between the carbonyls are the first to go, before the carbonyl double bonds themselves. (3)

SYNTHESIS AND EVALUATION OF NOVEL ANALOGS OF 1-PIPERIDINO-CYCLOHEXANE CARBONITRILE (PCC). R.L. Williams, and Kerita Kegler, Dept. of Chemical Sciences, Old Dominion University, Norfolk, Va., 23508. 1-Piperidino cyclohexane carbonitrile (PCC) 1 is a direct precursor to the illicit drug phencyclidine (PCP). We have begun a study associated with structural modifications of the PCC molecule in an effort to generate new biologically active compounds. The reaction of PCC under acid and basic conditions leading to a useful imidate 2 will be described together with our attempts to prepare the corresponding thiocyno analog 3 of PCC.



NOVEL PHOTOLYTIC AND CHEMICAL REACTIONS OF 1-(1-PHENYL-4-CYANO-4-PIPERIDYLCYCLOHEXYL)PIPERIDINE. R.L. Williams and Sharon Pickrel, Dept. of Chemical Sciences, Old Dominion University, Norfolk, Va, 23508. 1-(1-Phenyl-4-cyano-4-piperidylcyclohexyl)piperidine 1 was synthesized and evaluated for biological activity in our earlier work related to the synthesis of phencyclidine (PCP) analogs. This compound has now been shown to undergo what appears to be a unique reaction with either iodine in solution or with light to give a highly colored reaction product. These reactions will be described together with pertinent structural and spectral data as it relates to a possible reaction mechanism.



DECOMPOSITION REACTIONS OF 2,5-DISUBSTITUTED PYRIDINES AT 450°. Roobik Yaghoubi, Wayne M. Stalick, and George W. Mushrush, Department of Chemistry, George Mason University, Fairfax, VA 22030.

Jet fuels made from shale crudes have the highest n-alkane content and those from coal the lowest. The quantity of n-alkanes present in shale crude oil is insufficient to explain the n-alkane content (up to 37%) of jet fuels derived from shale oil. Aromatic compounds containing unbranched alkyl groups which rupture during thermal refining processes are considered likely sources of these n-alkanes. Based on capillary column GC/MS analyses of nitrogen compounds found in crude shale oil, alkyl pyridines were selected as model compounds for pyrolysis. The compounds pyrolyzed were 2-nonyl-5-methyl pyridine and 2,5-dinonylpyridine. They were pyrolyzed in stainless steel tubes at temperature and pressure conditions similar to the petroleum refining process known as delayed coking. Free radical attack at the alpha and gamma positions of the side chain were found to be favored. The complete product distribution and a mechanism consistent with the observed results will be presented.

## Education

"P OR J," HAVE IT YOUR WAY: THE GOVERNOR'S REGIONAL SCHOOL OF SCIENCE AND TECHNOLOGY. Michael L. Bentley, Col. of Education, Va. Polytechnic Inst., Blacksburg, Va. 24060 and Elizabeth Waring, Director, Mathematics and Science Center, Richmond, Va. 23223. The curriculum implementation process for the Governor's Regional School held at the Math-Science Center in the summer, 1985, utilized Jung's Psychological Type theory as a model for teaching/learning styles and communications. The Myers-Briggs Type Indicator (MBTI) was administered to staff and participants and workshops were held in applications. The project evaluation revealed that the model enabled participants to understand and appreciate learning and teaching style differences, which resulted in more cohesive and effective work teams. The school also featured a curriculum organized around high tech topics with an innovative organizational structure which promoted flexibility and promoted increased use of community resources. A follow-up program will be conducted at the same site in 1986. (Supported by a grant from the Va. Dept. of Education).

THE BEST GETAWAY -THE ONE-YEAR SABBATICAL. Patricia D. Borkey, Mathematics & Science Ctr., Richmond, Va. 23223. Public school science teachers have been leaving the profession in large numbers during the last decade. Many cite monetary reasons for the career change, but some list teacher "burn-out" as the greatest cause. Classroom teachers become so familiar with the curriculum and the process that they can tell the time of year by what they are teaching (the old "if its October, we are doing photosynthesis" syndrome). The Mathematics & Science Center, along with the Hanover County Public School system, developed a leave program for a classroom teacher to step out of the daily schedule, but still work in a teaching capacity. This was an opportunity to increase the curriculum areas and expertise at the Center as well as identifying a respected teacher in a Math and/or Science field. The rationale for such a plan, statewide, would be to keep experienced teachers with special skills in the classroom but, also, to provide stimulating new opportunities and lack of rigid scheduling.

CHEMISTRY IN THE COMMUNITY: A NEW CURRICULUM PROJECT FROM THE AMERICAN CHEMICAL SOCIETY. Vicki Clark, Program Specialist, Mathematics and Science Center, Richmond, VA, 23223. As technology continues to have positive and negative impacts on society, the public's need to understand chemistry increases. A curriculum project being developed by the American Chemical Society for high school students is responding to this need by teaching the science of chemistry in the context of societal-technological problems. Eleven private and public schools in the Richmond area are participating in a national field test of the CHEMCOM program. The Mathematics and Science Center is coordinating the local field test which includes teacher training and evaluation of the curriculum by teachers and students. The organization and implementation of the local field test will be described.

TEACHING SCIENCE-SOCIETY ISSUES. Julia H. Cothron, Department of Secondary Education, Hanover County Schools, Ashland, VA, & Vicki Clark, Mathematics and Science Center, Richmond, VA, 23223. Science-society issues were addressed through teacher inservice (NCC) courses and demonstration teaching. Course offerings included Bioethics, Technology and Society, and Environmental Dilemmas. The Preparing For Tomorrow's World curriculum materials were modeled in regular classrooms and special summer school programs. Evaluation of the NCC courses included pre-post tests of knowledge and of moral reasoning on ethical issues. Assessment of demonstration teaching included teacher and student perceptions. Preliminary data on the effectiveness of the first year and of the two-year program will be reviewed.

REDUCING THE FAILURE RATE AMONG SCIENCE STUDENTS AT JEFFERSON-HUGUENOT-WYTHE HIGH SCH. THROUGH THE IMPLEMENTATION OF A SCHOOL AND COMMUNITY AWARENESS PROGRAM. Calvin C. Green, Th.D., Head, Sci. Dept., JHW, Richmond, VA 23230-3802. A Practicum Intervention was conducted to improve the performance of science students in a transitional complex high school. The problem was identified with the inception of citywide semester examinations in 1981. Since then, as many as 70 classes in a building had failures in excess of 40 percent for a semester, and examination failures were as high as 98 percent. An analysis of the problem revealed that specific teachers were experiencing tremendously high failure rates, and that the ninth and tenth graders were failing courses, to some degree, because of examination failures. The methodology involved in the practicum was to conduct an awareness program for students, teachers, parents and administrators of the three-building high school. Three of four objectives set for the program were accomplished between March and November 1985. The biology year-end failures were reduced by nine percent; all of Huguenot science teachers were removed from the list of teachers having 40 percent or more failures for a subject; and earth science failures were reduced by 15 percent for the first report period. The researcher was unable to reduce the biology and chemistry examination failures by 30 percent.

GOVERNOR'S SCHOOL INTEREST CENTER IN FIELD BIOLOGY. H. S. Adams and M. L. Lipford, D. S. Lancaster Cmnty. Col., Clifton Forge, VA 24422. During summer, 1985, we conducted a Governor's School Interest Center in field biology on our campus. All participants were selected by counselors, principals, and science/biology teachers from middle and high schools in the service area of the college. Classroom and laboratory activities (terrestrial and aquatic ecology) were combined in a non-threatening learning environment with "hands on" wilderness experience (backpacking and canoeing). Pre- and post-examination of attitude toward biology and knowledge of ecological principles were conducted to evaluate student achievement. Attitude improvement among students was statistically detectable in three of four tests. Nearly 100 percent of all participants exhibited an increase in level of knowledge of ecology after two weeks of instruction. Quantitative questionnaires were completed by the students, and the Center was rated good to excellent in all categories. In conclusion, we believe this program has provided a unique opportunity for students in our rural setting to be involved in activities which have given them insight into structure and function of our world, and the research methods used to understand those relationships. This Interest Center has been refunded and will be conducted again in the summer of 1986.

A QUESTION/ANSWER/REACTION TEACHING MODEL. H. Kent Moore, Dept. of Physics, James Madison University, Harrisonburg, VA 22807. Described is a method designed to analyse the question, answer and reaction exchange, Q/A/R, between teacher and student in the science classroom. A hierarchy of two levels is assumed for the purpose of qualitatively rating each Q/A/R sequence that occurs during an instructional session. Level one exchanges are those which draw largely on knowledge recall, while those at level two require reasoning processes of a higher order. The method is seen having application to both pre-service and in-service teaching contexts.

THE PLANET EARTH TELECOURSE: A MODEL FOR CONTENT-INSERVICE FOR TEACHERS. Richard J. Rezba, School of Education, VA Commonwealth University, Richmond, VA 23284. More than 80 inservice teachers in the Greater Richmond Area participated in a unique telecourse, PLANET EARTH, the most comprehensive earth science series ever undertaken on national television. The principal focus was the improvement of the science content of teachers through a planned program of seven televised presentations and independent study, alternating with seven class meetings for content and some methodological discussion. The target population was three distinct groups: secondary earth science teachers, upper elementary teachers, and teachers of the gifted. Preliminary results were positive, both in attitude and cognitive gains. All three groups made significant gains between pre- and post-tests (50 items): elementary - 19 to 37; gifted - 20 to 39; and earth science 34 to 41. Teachers' open-ended responses indicated a need for more time devoted to how to teach much of the new information learned in the course. This project was funded by a grant from Title II, Education for Economic Security Act, awarded competitively through the State Council of Higher Education for Virginia.



CHEMISTRY IN THE COMMUNITY: A NEW APPROACH TO ISSUES, PROBLEMS AND OPPORTUNITIES FOR HIGH SCHOOL STUDENTS. Joyce W. Willis\*, Science Teacher, Jefferson-Huguenot-Wythe High School, Richmond, Va. 23221 ChemCom is a pilot course in Chemistry developed by the American Chemical Society with support from the National Science Foundation. ChemCom is an attempt to enhance science literacy through a curriculum that emphasizes the impact of chemistry on society. It is a "need to know" approach to teaching chemistry. I teach 4 Chemistry classes - 2 "regular", 1 Honors and 1 ChemCom. One of my objectives for this school year is to show that students taking ChemCom are able to think more logically and critically about problems confronting them in their daily lives and to analyze data more effectively than the "regular" Chemistry student, as measured by standardized and teacher-made tests. ChemCom is divided into eight modules: Water, Resources, Petroleum, Foods, Nuclear Chemistry, Air, Health and the Chemical Industry. The modules contain the major concepts, vocabulary, problem solving and laboratory skills expected in an introductory chemistry course. The early results show that ChemCom's are better able to question, observe and infer.

## Engineering

ON THE TRENDS IN FIGHTER AIRCRAFT DESIGN BY MEANS OF A US-USSR COMPARISON. O. Baysal\*, D. M. Baxter\*, Old Dominion University, Norfolk, VA., 23508, M. L. Spearman, NASA Langley Res. Ctr., Hampton, VA, 23665. An analytical prerequisite of planning the future is forecasting based upon careful analyses of past and present that establish the trends. The first step of this study has been the survey of existing both US and USSR designs. Among the characteristics studied are, maximum speed, sea-level rate of climb, wing design and wing loading, thrust-to-weight ratio, maximum lift-to-drag ratio, power loading, instantaneous and sustained turn rates, weight, and weight distribution. Comparison of the US and the USSR designs revealed extensive similarities as well as some differences. The comparisons of F-16A and MiG-29 and a close inspection of research aircraft X-29 are presented in an effort to provide a reasonable measure of the current US and USSR technologies. Forecasting the future trends in Western fighter aircrafts is not considered reliable due to the randomness of the data of their developments in the past. However, trends showed that Soviets use the proven technologies followed by evolutionary improvements. Therefore, a published prediction method is followed to extrapolate to the future Soviet fighter aircraft design; predicting a baseline configuration, which is used for an optimization and sizing program to determine the point design.

## BIOMEDICAL ENGINEERING AT VIRGINIA COMMONWEALTH UNIVERSITY

Alex M. Clarke, E. Carl Greco\*, William R. Krause\*, and Stanley E. Rittgers\*, Division of Biomedical Engineering, School of Basic Health Sciences, Medical College of Virginia, Virginia Commonwealth University, Richmond, VA 23298-0001. Established on July 1, 1984, and beginning with a faculty of two, the Program in Biomedical Engineering at the MCV/VCU, as of the Spring of 1986, has grown to four full-time faculty plus 11 affiliate faculty members. The program offers a Master of Science degree with bioinstrumentation and biomechanics tracts. Major areas of emphasis include the study of fabricated materials and natural tissues as well as the interaction between them, the development and evaluation of prosthetics devices for skeletal replacement and force analysis of the skeletal system, development of new, innovative devices to perform diagnostic, monitoring and therapeutic functions in a clinical environment, research on neurologic physiology, anatomy, chemistry and pharmacology to define systems behavior and responses.

A SCHOOL OF ENGINEERING'S ROLL IN INDUSTRIAL DEVELOPMENT, Ernest J. Cross, Old Dominion University, Norfolk, VA 23508.

Many industrial executives consider the connection with a local university important enough to substantially influence decisions concerning the location of new plants and other facilities. Old Dominion University is located within one of Virginia's largest urban areas and one of the fastest growing urban areas along the east coast of the country. A competent technical university can be a major community asset in attracting high technology companies and improving the regional economic base, and this is considered a principal concern and institutional responsibility of ODU. The engineering programs at ODU should be a major factor in strengthening the economic and industrial development of the Tidewater region. An Engineering Clinic has been established at Old Dominion University in order to provide a clear identity and high visibility for the engineering services which are available and to focus resources in order to provide the best possible community support for industrial development. The Clinic, which is supported by the Commonwealth Center for Innovative Technology, will provide engineering services and research laboratories for the support and assistance of regional businesses.

SYSTEM DYNAMICS MODELING OF INFRASTRUCTURE INDUCED DEVELOPMENT. Donald R. Drew, Dept. of Civil Engineering, Va. Polytechnic Inst., Blacksburg, Va. 24061. In recent years countries have been devoting a growing share of their national resources to infrastructure programs for meeting socio-economic development needs. While most of the civil engineered infrastructure in existence evolved step-by-step, it has become increasingly common, especially in newly developing countries, to think of engineering total infrastructure systems. Even for simple interventions associated with small projects, the factors that will determine the outcome must be identified, their relationships must be established, and secondary effects anticipated. In the case of massive interventions such as those associated with the case studies described in this paper, impacts may be dramatic and far removed from the points of intervention. Computer simulation modeling using the system dynamics methodology is shown to provide great potential as a dynamic instrumentality for generating infrastructure induced development plans.

THE COMMONWEALTH OF VIRGINIA COOPERATIVE GRADUATE ENGINEERING PROGRAM. Benjamin S. Blanchard, Virginia Tech; George L. Cahen, Jr., University of Virginia; Thomas W. Haas, Virginia Commonwealth University; William J. McMahon, Jr., Old Dominion University, and George R. Umberger, George Mason University. Under the auspices of the Cooperative Graduate Engineering Program, the University of Virginia (UVA) and Virginia Polytechnic Institute and State University (VPI&SU), in cooperation with Virginia Commonwealth University (VCU), Old Dominion University (ODU), and George Mason University (GMU), along with the Virginia Public Television Stations and the Department of Information Technology (DIT), will deliver televised graduate engineering courses throughout the Commonwealth of Virginia. In Richmond, Hampton Roads, and Northern Virginia, VCU, ODU, and GMU, respectively, will act as the "host" institution or administrator of the program. In order to serve other regions of the Commonwealth, the engineering courses will be distributed by satellite starting in Fall 1986. This will enable courses to be received at the Institute of Manufacturing Technology, Inc., Center for Advanced Engineering in Lynchburg, at Mary Washington College in Fredericksburg, at Clinch Valley College and at the UVA Continuing Education Center in Abingdon, both in Southwest Virginia as well as those industrial sites equipped with c-band downlinks.

THE EFFECT OF TREATMENT PROCESS VARIABLES ON THE THICKENING AND DEWATERING CHARACTERISTICS OF WATER PLANT SLUDGES. Jeff R. Hamon\*, and William R. Knocke\*, Dept. of Civil Engr., Va. Polytechnic Inst., Blacksburg, Va. 24061. The objective of this study was to determine the effects of coagulation pH and influent turbidity on the characteristics of aluminum and ferric hydroxide sludges. To reduce experimental error, sludges were produced under specific operating conditions using a 400 l/day continuous-flow reactor. Results to be presented include changes in sludge thickening and dewatering characteristics caused by operating condition variation, and the role of sludge micro-properties in these changes. Possible effects of operating condition variation on effluent quality will be discussed.

ENGINEERING RESEARCH AT THE UNIVERSITY OF VIRGINIA. Ralph A. Lowry, School of Engineering and Applied Science, Univ. of Va., Charlottesville, VA 22901. Many doctoral degree programs in engineering in the United States are relatively new, being in existence only about 25 years. As these graduate programs have matured, engineering research at universities has changed in nature and gained greatly in both quantity and quality. Rapid changes are still taking place in research in engineering schools across the Nation. Interdisciplinary research is being emphasized, research facilities are being updated and expanded, interaction with and participation of industry are playing a greater role, and in many areas closer ties with science departments are developing. These characteristics of today's engineering research are illustrated by a brief overview of some of the research activity in the School of Engineering and Applied Science at the University of Virginia.

FINITE ELEMENT ANALYSIS OF LOCALIZED STRESSES AT BRANCH POINTS OF ARTERIES. Lancelot Manuel\*, Richard T. Eppink\*, Dept. of Civil Engrg., Mano J. Thubrikar\*, Dept. of Surgery, University of Virginia, Charlottesville, VA 22901 Atherosclerotic lesions develop predominantly at the branch sites of arteries. Stress intensification at these sites could be important in atherogenesis and so these stresses were studied analytically and experimentally. A finite element analysis was undertaken wherein the arterial branch was modelled as two intersecting thin cylindrical shells. An incremental pressure loading of 40 mm Hg and longitudinal tethering forces were applied to the model. The geometry and material properties were determined from in-vivo experiments on the canine iliac bifurcation. Thickness variations in the branch area and orthotropic properties were considered. The material was considered to be linearly elastic in the pressure range of the experiment. Experimental strains were determined at various sites over a range of pressures from 80 to 120 mm Hg and were compared with analytical strains. The results indicate localized areas of high stress concentration. In one model the stresses at the branch area were fourteen times that in the straight artery. The degree of stress concentration is affected mainly by the branch angle and by the thickening at the branch, and only to a small extent by the tethering force and elastic properties.

ENGINEERING ASSESSMENT OF A COPPERAS WASTE DISPOSAL SITE IN PINEY RIVER, VA. Mark S. Morris, \*John T. Novak and William R. Knocke, Dept. of Civil Engr., Va. Polytechnic Inst. & State Univ., Blacksburg, VA 24060. Waste ferrous sulfate (copperas) generated as a by-product of titanium oxide production has caused major water quality problems in several U.S. locations. This material, when contacted with water, produces an acidic stream that can have devastating environmental effects. This paper presents the results of one such site in Virginia.

VIRGINIA TECH'S COMMITMENT TO TRANSFER STUDENTS. Leo A. Padis, Engineering Administration, VPI & SU, Blacksburg, Va. 24061. Undergraduate credit towards a bachelor's degree must be earned while enrolled as an undergraduate student. There are occasions when students may accumulate other undergraduate credit in addition to that earned at Virginia Tech. Such credit may be based on completion of equivalent course work at other accredited collegiate institutions and education and/or experiences other than that obtained in formal course enrollment at Virginia Tech. There are four categories into which these fall. They are 1) transfer credit, 2) advanced placement credits, 3) advanced standing, and 4) credit-by-examination. A description of each and related policies is given. No more than 50% of the credits required for graduation may be transferred from two-year programs or colleges. The maximum number of credits that may be transferred to Virginia Tech is based on the senior residency rule; that is, a senior year with a minimum of 45 quarter hours must be completed in residence or 45 of the last 60 quarter hours must be completed in residence provided that only approved elective courses taken in absentia are transferred to complete requirements. Of particular interest are how international baccalaureate credits are handled and credits from foreign colleges and universities.

WHEELCHAIR FRAME FAILURE ANALYSIS. Beth A. Todd\*, John G. Thacker\*, and Timothy M. Duffey\*, Univ. of Va. Rehabilitation Engineering Ctr., Charlottesville, Va. 22903. Low-cycle fatigue is considered as the cause of wheelchair frame failure. Static analysis established the load distribution due to a wheelchair user. Differences between maximum static stress locations and failure points led to a consideration of dynamic failure mechanisms. Three design changes for increasing frame life are suggested. (Funded by NIH Grant #G00-98300072.)

GEORGE MASON UNIVERSITY INITIATIVES IN INFORMATION TECHNOLOGY AND ENGINEERING. George R. Umberger \*, Director, Cooperative Graduate Engineering Program, School of Information Technology and Engineering, George Mason University, Fairfax, VA 22030. A review of the development of George Mason University (GMU) in response to corporate requests for academic support in the growing high-technology community of Northern Virginia. Initiatives began in 1981 with the formation of the George Mason Institute of Science and Technology (GMI), a collective of corporate and University executives organized to promote cooperation and collaboration in instructional, research and service activities. From GMI grew the GMU School of Information Technology and Engineering, with academic programs focusing on information-based sciences. Several research centers, conferences, endowment efforts, and related activities are also a direct result of GMI. The Institute for Information Technology, focusing on research activities, is one example of this engineering and high technology thrust. The State-initiated Cooperative Graduate Engineering Program, a consortial academic program with the University of Virginia and Virginia Tech, is an example of reaching out to the corporate community in engineering education. Research dollars, student enrollments, and corporate liaison activities in several areas are rapidly expanding, and GMU is developing a thriving presence in high-technology.

FATIGUE RESPONSE OF A FIBER REINFORCED PLASTIC PEDESTRIAN BRIDGE. Timothy R. Zimmerman\* and Fred C. McCormick, Dept. of Civil Engineering, University of Virginia, Charlottesville, Va. 22903. Response of a glass fiber reinforced plastic pedestrian bridge to repeated static loads is studied. The bridge is subjected to various load configurations and magnitudes totalling some 1.5 million cycles. Static test loads are applied periodically during which the structure's response is observed. Deflections, strains, acoustic emission data, and visual inspections are used to describe progressive failure due to fatigue.

## Environmental Science

THE DISTRIBUTION AND ABUNDANCE OF THE BOTTLENOSE DOLPHIN, TURSIOPS TRUNCATUS (MONTAGU 1821), IN VIRGINIA. R. A. Blaylock\*, Virginia Institute of Marine Science, Gloucester Point, VA, 23062. Aerial surveys were conducted in July-October 1980, and May-June 1981, in the Chesapeake Bay mouth and the nearshore coastal waters of Virginia south of Cape Charles to assess the distribution and abundance of bottlenose dolphins. Chesapeake Bay mouth surveys yielded a strip census herd density of  $0.004 \text{ herds/km}^2$ , a mean herd size of 32.8 dolphins/herd, and a dolphin density of  $0.13 \text{ dolphins/km}^2$ . Virginia coastal surveys (within 2 km of shore) in 1980 and 1981, totaled 435.1 linear km producing a strip census herd density of  $0.044 \text{ herds/km}^2$ , a mean herd size of 33.7 dolphins/herd, and a dolphin density of  $1.47 \text{ dolphins/km}^2$ . Coastal line-transect surveys during the summer of 1980 (for a population estimate) resulted in a mean herd density of  $0.081 \text{ herds/km}^2$  and a dolphin density of  $2.73 \text{ dolphins/km}^2$ . The population size was estimated to be 340 dolphins (95% CI =  $\pm 72$ ). Dolphins were sighted primarily within 1.6 km of the shore. There was a direct relationship between monthly mean herd density and water temperature. Of seven dolphins identified 1980, five were resighted in 1981. There was no apparent relationship between the number of reported strandings and estimated monthly abundance.

### DEGRADATION OF TERTIARY BUTYL ALCOHOL BY SUBSURFACE SOIL BACTERIA.

James B. Chadduck, Robert E. Benoit, and John T. Novak, Departments of Biology and Civil Engineering, Virginia Polytechnic Institute and State University. Tertiary butyl alcohol (TBA) is a water soluble component of some gasohol mixtures. It is a potential groundwater contaminant from leaky underground gasoline storage tanks. The degradation of TBA was measured using groundwater microcosms and bacteria isolated from enrichment cultures of subsurface soil. Soil was taken from four sites at depths ranging from 10 to 100 feet using conventional drilling equipment. One of the sample sites was contaminated with gasoline containing TBA and the other three sites were not contaminated. Degradation rates for the uncontaminated sites were very slow. Degradation proceeded at a significant rate in the microcosms and enrichment cultures from the contaminated subsurface soil. Degradation of TBA by enrichment cultures in a defined medium containing 10 to 500 ppm TBA was observed under aerobic and microaerobic conditions but not under anaerobic conditions. An organism capable of degrading TBA as a sole carbon source was isolated from the contaminated soil. Degradation of TBA by the isolate was also observed under aerobic and microaerobic conditions but not under anaerobic conditions.

MOLLUSCS OF THE HYPERSALINE LAKES OF SAN SALVADOR ISLAND, BAHAMAS. Glen Clowdis, Lynchburg College, Lynchburg, VA 24501. This project was undertaken to survey the various species of molluscs of the hypersaline lakes of San Salvador, Bahamas, and attempt to correlate certain species with tolerance to salinity. The molluscs are relatively uniformly distributed throughout the lakes. Eleven species, representing nine families, were found through random sampling. Those species found at every collection site are Polymesoda maritima (fam. Corbiculidae), Batillaria minima (fam. Potamididae), and Cerithidea costada (fam. Potamididae). The extraordinarily high salinities of the lakes surveyed: Little Lake - 43 p.p.t.; Great Lake - 90 p.p.t.; Long Lake - 100 p.p.t.; Granny Lake - 80 p.p.t.; and North Granny Lake - 85 p.p.t.; apparently cause phenomorphological changes in the family Potamididae as B. minima and C. costada are 28.6% and 30.88% smaller, respectively. Other noticeable variances of B. minima and C. costada are less distinctive whorls of the shells, and less definition of the vertical ribs when compared with shells from less saline waters.

METEOROLOGICAL ASPECTS OF THE NOVEMBER 1985 VIRGINIA FLOOD. Stephen J. Colucci, Dept. of Envi. Sci., University of Virginia, Charlottesville, Va. 22903. Up to twenty inches of rain fell on portions of Virginia during the period October 31-November 5, 1985, producing the most destructive flooding in some locations in more than a decade. The heavy rains began as Hurricane Juan passed northward to the west of Virginia on October 31. Following this passage, a surface high pressure system intensified over New England and a second low pressure system moved northward along the Appalachian Mountains. A strong pressure gradient thus developed over Virginia, resulting in easterly flow and topographically forced ascending air perpetuating the heavy rain. It is hypothesized that Hurricane Juan modified the large-scale circulation permitting the enhancement of the surface pressure gradient and prolonged heavy rains.

FEEDING ECOLOGY OF THE AMPHIPOD, GAMMARUS MINUS. Carol J. Haley and Arthur L. Buikema, Jr., Dept. of Biol., VPI&SU, Blacksburg, VA 24061. Preliminary studies of Gammarus minus populations in two streams of different morphology and vegetation showed that the amphipod tends to occur in four habitats within the streams and that juveniles and adults tend to be segregated from one another within a stream. It was hypothesized that different size classes or populations use different feeding strategies. As part of the study of feeding strategies, SEM and light microscopy were used to determine fine structure of mandibles, maxillae, and maxillipeds of adults and juveniles. No major differences between juvenile and adult mandibles have been detected. However, the palps of right first maxillae of juveniles from one stream generally have fewer teeth than those of adults in that stream. The variety of foods found in guts indicates that G. minus is capable of handling several types of food. Sturdy, toothed mandibular incisors and right first maxillary palps may be used in shredding leaves and other vegetation or in slicing filamentous algae. The variety of kinds of setae and the abundance of setae on the first maxillae and maxillipeds indicate a potential capability for filtering. The significance of tooth number on maxillary palps remains to be determined. (Supported by grants from Sigma Xi and VAS)

TERRESTRIAL CONSUMER BIOACCUMULATION OF MERCURY ON THE SOUTH RIVER FLOOD PLAIN WAYNESBORO, VA. Hayes, Robert, Peter T. Nielsen, & W. Dean Cocking. Dept. of Biology, James Madison University, Harrisonburg, VA 22807. Mercury bioaccumulation was observed within terrestrial decomposer and consumer populations living on the South River flood plain in Waynesboro, VA. High and low soil mercury sites containing a variety of plant communities were selected downriver and upriver from the original point source of contamination. Mean total mercury residues in earthworms (Lumbricus spp.) from the high mercury sites ranged from 3.7 to 9.9 ppm ( $\mu\text{g/g}$  lyophilized weight) with none greater than 1 ppm in those collected from low level sites. Interspecies differences were noticable for small mammals, probably due to differences in feeding habits. For example, kidney tissue was found to have the highest accumulation, ranging from 2.0 ppm in Peromyscus leucopus to 30 ppm in Blarina brevicauda. Mercury residues in Microtus pennsylvanicus were almost negligible.

CATCH AS CATCH CAN: AVAILABILITY AS A MEDIATOR OF FORAGE-FISH SUPPLY TO SPORTFISH PREDATORS IN A VIRGINIA RESERVOIR. John J. Ney and Mark S. Tisa, Dept. of Fish. & Wildl. Sci., Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061.

Vulnerability of a potential prey is determined by its morphological, distributional, and behavioral availability to the predator: it must be ingestible, coincide in space and time, and be catchable. Smith Mountain Lake has two abundant forage species, alewife and gizzard shad, and three piscivorous sport species - walleye, striped bass, and largemouth bass. We examined spawning periods, growth and mortality rates, and distribution of prey and predator species to assess the complementarity of alewife and gizzard shad in providing an available forage supply. Because alewives spawn later and grow more slowly, they remained morphologically available to juvenile piscivores; shad quickly become invulnerable. Alewife and gizzard shad also occupy different habitats; alewives are pelagic and abundant downlake while shad are littoral and frequent the riverine uplake area. Diets of predators substantiate the differential availability of the forage fish. Juvenile piscivores feed heavily on alewives but not shad, as does the pelagic and size-limited walleye. In contrast, largemouth bass are littoral and feed predominately on shad. Striped bass have a cosmopolitan distribution and wide size range; shad and alewife contribute equally to their diet.

HALOPHYTES OF THE HYPERSALINE LAKES OF SAN SALVADOR ISLAND, BAHAMAS. W. Guy Rivers, Dept. of Biol., Lynchburg College, Lynchburg, Va., 24501. Approximately 80% of the Earth's surface is covered with a saline solution of about 29-36 ppt. (.5 M NaCl). Few higher plants can tolerate such saline conditions. Those that do are collectively known as halophytes.

The island of San Salvador, Bahamas contains a number of lakes with salinity greater than the salinity of the oceans. In several of these lakes the salinity exceeds 75 ppt.

During the months of February and March 1985 visits were made by canoe to a number of the inland hyperhaline lakes on San Salvador Island. Collections of plants and water sample collections were made. Specific gravity and density determinations at 15° Centigrade were made by hydrometer and converted to salinity ppt.

Efforts were made to correlate water salinity and distribution of halophytic plant communities. Species that seemed to be most euhalophytic were noted.

THE KOHOUT CELL - A NEW MARINE BIOGEOCHEMICAL CYCLE. G.M. Simmons, Jr., Biol. Dept., Virginia Tech, Blacksburg, VA 24061. Movement of water across the sediment/water interface in a marine habitat can have an important effect on benthic communities and those planktonic communities in the attendant water column. Such water movement, in flushing the sediment/water interface, is an important pathway for recycling chemical compounds into the sea. Productivity may be stimulated if the water contains nutrients. Conversely, if the ground water or the sediments through which it moves contain synthetic chemicals or heavy metals in toxic concentrations, perturbation may result. Recent research off Key Largo, Florida corroborates a previously untested theory proposed nearly three decades ago regarding continuous cyclic sea water flow between the open sea and marine sediments along the Zone of Diffusion in front of a fresh ground water table. Data collected thus far show this cyclic movement of sea water - the Kohout Cell - to be extremely important in recycling nutrients and minerals back into the sea. When compared to individual river basins on an area to area basis, the Kohout Cell recycles 2-4 orders of magnitude more of trace minerals and equals a given river basin in nitrate and total phosphate discharge. The Kohout Cell should operate along any continental land margin that has a sufficient ground water table to generate it.

A SPECIES SURVEY OF THE HYPERSALINE LAKES OF SAN SALVADOR ISLAND, BAHAMAS. B. Keith Taylor, Biol. Dept., Lynchburg Col., Lynchburg, Va. 24501. Collections of fish species were made at three isolated lakes or pools on San Salvador Island in the Bahamas using small mesh seines or hand-held nets. Two species were found to be present in the inland island lakes, Cyprinodon variegatus (Sheeps-head Minnow) and Gambusia puncticulata manni (Mosquitofish). Water samples were taken at each of the collection sites and the salinity of each sample was determined by use of a conductivity meter. The salinity of the samples taken from the inland lakes was found to range from 40 to 190 ppt. An unexpected find in this survey was the collection of Cyprinodon variegatus living in an inland pool with a salinity approximating 190 ppt.

MERCURY CONTAMINATION IN SOUTH RIVER FLOOD PLAIN SOILS AT WAYNESBORO, VA. Thomas, Ron, Deanna M. Ward, Robert Hayes, Peter Nielsen, and W. Dean Cocking. Dept. of Biology, James Madison Univ., Harrisonburg, VA 22807. Mercury contamination in bottom sediments and adjacent flood plain soils of the South River occurred prior to 1950. In 1980, the Virginia State Water Control Board estimated that 37,000 kg of mercury were deposited on 250 ha of the flood plain with an average concentration of 10.7 ppm downstream from the mercury point source. Several terrestrial communities within 30m x 80m grids were systematically studied for the presence of mercury in both biotic and soil compartments. Old field, intermediate-age old field, and forest communities soils at sites located 5 km downstream from the point source averaged 16.8 ( $\mu\text{g/g}$  dryweight), 8.2 ppm, and 22.0 ppm respectively. Similar upstream communities occurred on soil with less than 0.25 ppm mercury. All samples were analyzed for total mercury content with atomic absorption spectrophotometry.

TERRESTRIAL PRODUCER BIOACCUMULATION OF MERCURY ON THE SOUTH RIVER FLOOD PLAIN, WAYNESBORO, VA. Ward, Deanna M., Peter T. Nielsen, and W. Dean Cocking. Dept. of Biology, James Madison Univ., Harrisonburg, VA 22807. Bioaccumulation of mercury occurs in terrestrial plant communities on the South River Flood Plain, at Waynesboro, Virginia. A successional forest community growing on soil with a high mercury concentration of 22.0 ppm ( $\mu\text{g/g}$  dryweight) was compared to a similar forest stand located on soil of less than 0.25 ppm. Tissues collected over a three year period were acid rinsed, air dried, and pulverized prior to wet digestion with nitric and sulfuric acids. Total mercury content in vascular plants was highest in the root tissues, ranging from 0.26-2.39 ppm in the tree species, and between 0.86-3.11 ppm in the herbs. Root tissues at the low level site contained less than 0.2 ppm. In 1985, mercury accumulation in leaf tissues ranged between 0.13-1.9 ppm and 0.08-0.29 ppm at the high and low level sites, respectively. Twig, bark, stem, heartwood, and reproductive tissues had trace or undetectable amounts of mercury.

INVESTIGATION AND ASSESSMENT OF THIRTEEN UNLAWFUL SOLID WASTE ACCUMULATIONS IN NORTH AND CENTRAL BEDFORD COUNTY, VIRGINIA. Robert A. S. Wright, Department of Biology, Lynchburg College, Lynchburg, Virginia 24501.

This presentation focuses on nonpoint pollution emanating from unlawful solid waste accumulations found in roadside ditches, stormwater culverts and streambeds throughout the northern and central sections of Bedford County. Several areas were classified as "watershed contamination dumpsites" because of potential or real surface water organic and petroleum product leachate contamination.

Color slides document the pollutants in each area, and severely contaminated dumpsites are featured in the presentation. The findings of this research were submitted in a report to the Bedford County Administrator for appropriate action. It is hoped that the report can assist officials in damage assessment and further analysis of these and other similar areas throughout the County.



EMPIRICAL PREDICTION OF FISHERY PRODUCTIVITY IN A VIRGINIA RESERVOIR. Jeffrey J. Yurk and John J. Ney, Dept. of Fisheries and Wildlife, Va. Polytechnic Inst. and State Univ., Blacksburg, Va. 24061. Phosphorus concentrations in Smith Mountain Lake, a central Virginia hydroelectric reservoir have declined since 1975, concurrent with decreases in the fishery. Log transformed total phosphorus concentrations and fish standing stock estimates for Smith Mountain Lake (1973-1984) were modeled using simple linear regression techniques to determine the utility of phosphorus as a predictor of the fishery. Significant results ( $p=0.105$ ) were obtained when regressing forage fish ( $r=0.57$ ), total standing stock ( $r=0.44$ ), benthophagous fish ( $r=0.48$ ), and piscivorous fish ( $r=0.15$ ) with total phosphorus concentrations matched by lake area and time. Single-species standing stocks were also regressed against total phosphorus; correlations ranged from  $r=0.15$  for largemouth bass (*Micropterus salmoides*) to  $r=0.56$  for gizzard shad (*Dorosoma cepedianum*). When these species were subsetted into age classes, best fits to the log model occurred for age-2 gizzard shad ( $r=0.62$ ) and age-2 largemouth bass ( $r=0.30$ ). Lagging of fisheries data one and two years behind phosphorus concentrations did not improve predictability.

## Geology

A RECONNAISSANCE STUDY OF INTRUSIVE AND METAVOLCANIC ROCKS BETWEEN THE SOUTH-EASTERN BORDER OF THE RICHMOND BASIN AND THE PETERSBURG GRANITE IN THE EASTERN-MOST PIEDMONT OF VIRGINIA. Bruce K. Goodwin, Dept. of Geology, Col. of William and Mary, Williamsburg, Va. 23185, & C. R. Berquist, Jr., Va. Division of Mineral Resources, Charlottesville, Va. 22903.

The area between the eastern border of the Richmond Basin south of Swift Creek Reservoir and Coastal Plain sediments to the east is underlain by two lithologically distinct regions separated by a thrust fault trending N20W and dipping to the east. To the west of the fault is a sequence of felsic and mafic metavolcanic rocks composed of metadacites and/or metarhyolites, metamorphosed volcanoclastic rocks, and amphibolites. These rocks may be a northern extension of the Eastern Slate Belt of North Carolina. The granite adjacent to the fault is highly sheared, shows crushed grain boundaries, and often contains parallel K-feldspar porphyroblasts. To the east of the fault is Petersburg Granite and biotite gneiss which has been intruded by the granite. One 21 km long and .8 km wide band of biotite gneiss and amphibole gneiss trending N20W to N30W and commonly exhibiting a cataclastic texture cuts the granite. It suggests that the granite-biotite gneiss region is thrust faulted and is broken up into at least two and possibly more thrust sheets.

THE QUALITY OF VIRGINIA GROUNDWATER: A GEOCHEMICAL APPRAISAL. H.G. Goodell and G.M. Hornberger, Dept. of Env. Sci., Univ. of Virginia, Charlottesville, Va 22903. Most of the groundwater used in Virginia is produced from shallow water table aquifers and its natural chemistry reflects the mineralogy of its host rock. The average major and selected minor ion composition of the groundwater of 95 counties and localities has been determined using 5494 water analyses. Counties with similar geology were used to develop hydrogeochemical profiles of major groundwater regions. Over the Valley and Piedmont  $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$  and  $\text{HCO}_3 > \text{SO}_4 > \text{Cl}$ . In the Plateau and Coastal Plain  $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ . Plateau anions are similar to those in the Valley but in the Coastal Plain  $\text{HCO}_3 > \text{Cl} > \text{SO}_4$ . Statewide the minor elements F, Zn, and Fe dominate followed by  $\text{Al} > \text{Ni} > \text{Mn} > \text{Cu} > \text{Ba} > \text{Pb} > \text{Hg} > \text{Cd}$  with important differences between regions. F is highest in the Coastal Plain; Fe and Zn in the Plateau; Al, Cu, Pb and Ba in the eastern Piedmont; Ni and Cd in the Valley; Hg in the Blue Ridge. Average TDS for the state is 377 ppm with a high of 520 ppm in the Coastal Plain and a low of 116 ppm in the Blue Ridge.

PROROSMARUS ALLENI, A GIANT WALRUS, FROM THE YORKTOWN FORMATION (PLIOCENE), WILLIAMSBURG, VIRGINIA. M.S. Harris\* and G.H. Johnson, Dept. of Geol., College of William and Mary, Williamsburg, VA 23185. A nearly complete ulna of a fossil walrus, tentatively assigned to Prorosmarus allenii Berry and Gregory, 1906, was discovered in shelly sand of the Yorktown Formation in Williamsburg, Virginia. The holotype of P. prorosmarus is based upon a left mandibular ramus collected from drift at Yorktown and is probably from the Rushmere or Morgarts Beach members of the Yorktown Formation. The newly discovered ulna is from the upper part of the Placopecten clintonius biozone or Sunken Meadow Member and is assigned to P. allenii on the basis of its morphologic similarity to European specimens and its stratigraphic position. This ulna is the only one known from North America and extends the stratigraphic range of this species into the lower Pliocene.

AN EVALUATION OF SALTWATER INTRUSION AND GROUNDWATER QUALITY ON THE EASTERN SHORE OF VIRGINIA. Thomas King and H.G. Goodell, Dept. of Env. Sci., Univ. of Virginia, Charlottesville, Va. 22903. The extent of saltwater intrusion in Northampton and Accomac Counties on the Delmarva Peninsula, has been determined using electromagnetic terrain conductivity (EM). Six EM coil configurations were used to achieve varying penetration depths and cumulative instrument responses. Initial analysis of contoured EM data indicates limited saltwater intrusion coincident with high conductivity values along the western margin of the peninsula where salt and brackish water creeks dissect the coast. Low EM readings also delineate regions in the interior of the peninsula where the saltwater interface is depressed below the depth of maximum instrument penetration. Additionally, multilayer modeling of surface EM response to known groundwater quality and formation resistivity suggests a functional relationship between apparent conductivity and depth to saltwater-freshwater interface.

TIDE SPRING VIRGINIA--OBSERVABLE PARAMETERS. JAMES D. LEHMAN, Dept. of Physics, James Madison Univ., Harrisonburg, VA. 22807. The overall performance of this ebb-and-flow spring has been observed carefully for 45 months. Timewise, four modes of flow are evident: Periodic-41%; Erratic-31%; Dry-25%; Continuous-3%. The spring mode and volume of discharge are very dependent on the local precipitation pattern. Although water only overflows from a one-meter diameter bowl-shaped opening, the surface area of the spring body appears to be quite extensive. Flow trends between wet and dry periods are predictable. These include the variable time between flow starts, water level during quiescent period between flows, and changes in the volume of overflows. The period of oscillation at flow's end is a constant suggesting a temporary "hydraulic jump" of common surfaces. The overall performance of periodic activity is believed to be the work of a holding reservoir and self-cycling siphon located remotely from the spring by several hundreds of feet.

COAL BEDS OF THE POCAHONTAS AND LEE FORMATIONS IN WISE COUNTY- A PRELIMINARY APPRAISAL. Jack E. Nolde, Va. Div. of Mineral Resources, 468 E. Main, Room 100, Abingdon, Virginia 24210. The Lower Pennsylvanian rocks in Wise County consists of quartz arenites, lithic graywackes, siltstones, and coals of the Pocahontas, Lee, and Norton formations. The lower beds of the Pocahontas and Lee formations lie unconformably upon the Mississippian Bluestone Formation. The Lee Formation varies between 900 and 1500 ft thick and comprises deltaic and nearshore marine facies. West of Tacoma, the Lee is primarily quartz arenite and siltstone with at least 5 coal beds greater than 14 inches. East of Tacoma, there are at least 14 coal beds greater than 14 inches where the quartz arenites grade laterally to lithic graywackes of the Norton Formation. The Norton below the Kennedy coal is as much as 600 ft thick and includes deltaic facies. The Pocahontas is only present east of Tacoma and is as much as 500 ft thick near St. Paul. The Pocahontas beds are composed of deltaic facies and are overlain unconformably by the Lee Formation. The areal distribution and thickness of the sandstone units determine the areal extent of the coals. Coal beds useful for correlation in Wise County are the Kennedy, Raven, Jawbone, Lower Seaboard, War Creek, Cove Creek, and the Pocahontas coals.

GROUNDWATER ALONG THE FALL ZONE: AN OVERVIEW James V. O'Connor D.C. WRRRC, Univ. of D.C., 20008. The groundwater regime in the Fall Zone has a documented history. Piedmont rocks differ chemically from fall's city to city. Depth of saprolite and fracture systems regulate the quantity and quality. Coastal Plain depositional history is critical to tracking and monitoring chemical changes. The Potomac aquifer recharge area lies along the east side of the Fall Line. A classification system for natural or artificial springs helps monitor quality and quantity with time. City environs encounter many problems beyond potability. Some daily problems are dewatering, addwatering, leaks, piping, frozen ground, water logging, soil alterations, increased or redirected flow, subsidence, slides, blast fractures, tunnels, chemical interactions, historical dump sites and dredge spoil drainage. Groundwater laws at all levels are drastically changing from the simple riparian and reasonable use doctrines. Groundwater is a limited resource which must be protected and managed for all uses during urban sprawl and vertical construction. Our groundwater data base has not been collated into a useful system for predicting behavior for onsite specific cases but should be.

FRESHWATER/SALTWATER DYNAMICS BENEATH A VIRGINIA BARRIER ISLAND. Leonard Rafalko and H.G. Goodell, Dept. of Env. Sci., Univ. of Virginia, Charlottesville, Va. 22903. Field results from Hog Island, a Virginia barrier, show that theoretical values describing the depth to the saltwater-freshwater interface as proportional to the elevation of the water table above sea level are not valid. The freshwater-saltwater relation was examined using 13 wells installed at variable depths along a latitudinal transect on Hog Island. Profiles of salinity against depth at well clusters along the transect, show that salinity initially increases with depth, followed by abrupt decreases. Variable well hydraulic conductivities suggest that heterogeneous subsurface permeabilities can influence the quality of the groundwater by affecting the ability of recharge to flush saltwater from the sediments. The vulnerability of the freshwater to saltwater contamination was demonstrated by Hurricane Gloria (1985). Pre-hurricane measurements showed a thin veneer of freshwater existing along the island. Post-hurricane measurements demonstrated the effects of overwash events as salinity values increased in nine of the wells. Evidence of seawater contaminations still exists 7 months later. Thus, the freshwater/saltwater relation is a delicate and dynamic system influenced by subsurface heterogeneities and high magnitude transient storm events.

ELECTRIC ANALOG MODELING OF STREAMFLOW AS A MEANS OF ESTIMATING THE RATIO TRANSMISSIVITY/STORATIVITY IN A SMALL WATERSHED IN NORTHERN VIRGINIA. John E. Sander\* & Douglas R. Brown\*, Dept. of Geol. & Geog., James Madison University, Harrisonburg, Va. 22807. A recently developed method using baseflow measurements of stream discharge in conjunction with electric analog modeling techniques was employed to obtain estimates of the ratio of transmissivity/storativity for a small watershed in northeastern Virginia. If these hydrologic parameters are uniform over a watershed, then this technique will accurately reflect the ratio. If only a portion of the watershed is permeable, then modeling results can be used to estimate the percentage of permeable rock. Modeling results for this small watershed are in agreement with estimates of these hydrologic parameters as well as estimates of the areal extent of permeable rock in the watershed. This analog approach shows potential for further development using digital computer techniques.

SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE UPPERMOST MARTINSBURG AND "CUB" SANDSTONE AT CATHERINE'S FURNACE. Brian L. Sherrod\* and Lynn S. Fichter\*, Dept. of Geology, James Madison Univ., Harrisonburg, Va. 22807. A bed by bed analysis of the exposure along Route 685 near Catherine's Furnace, Page County, Va., suggests that the sediments represent a prograding, storm dominated shelf, with minor tidal influences. Interpretations were based on primary sedimentary structures and patterns of sequences and cycles. The section has three subdivisions, exhibiting an overall thickening and coarsening upward sequence. The lower 1/7 of the section is sparsely fossiliferous, cyclical siltstones and shales, interpreted as a quiet, deeper water shelf. The facies of the lower 1/7 continue into the middle 3/7 but interbed with sequences of megarippled fossil packstones and hummocky beds, interpreted as storm events in a midshelf. The upper 3/7 has thicker, coarser sands with planar cross beds and high velocity laminations. The planar cross bedding may be from tidal currents. The upper sands are interpreted as a near-shore shelf. These facies are similar to the better preserved Reedsville (Martinsburg) in West Virginia and southwest Virginia.

STRATIGRAPHY AND ORIGIN OF THE BON AIR GRAVEL, SOUTHWEST OF RICHMOND, VA. Ross A. Steenson, Col. of William and Mary, Williamsburg, Va. 23185. Bon Air gravel is an informal name given to an upland gravel deposit in the Upper Coastal Plain which occurs south of the James River, west of Richmond in Chesterfield County, Virginia. The Bon Air gravel contains a sequence of interbedded coarse gravels, fine to coarse sands and silty clays which unconformably overlies orange silty clays, clayey silts and silty, fine sands. Some workers have interpreted the origin of similar deposits throughout the Atlantic and Gulf Coastal Plains as marine while others have considered the origin to be fluvial.

The sediments underlying the Bon Air gravel are interpreted to be tidal flat deposits because of their lenticular to flaser-bedded nature and presence of the trace fossil Ophiomorpha. The Bon Air gravel is interpreted to be of fluvial origin because of the nature of the gravels within the sequence. Bedding in the gravels is indistinct and the gravels occur in distinct channel fill deposits or are laterally irregular. Clays in the Bon Air gravel may be overbank deposits or because of physical characteristics similar to the underlying sediments, may be tidal flat-estuarine deposits. Well-defined gravel beds and pebble layers in the eastern portion of the study area suggest a marine influence in the east. (Supported by the Minor Res. Grants Program at the Col. of William and Mary)

## Materials Science

**SCANNING AUGER MICROPROBE TECHNIQUES.** Robert A. Bayles, Code 6312, Naval Research Laboratory, Washington, DC 20375-5000. When an energetic electron beam strikes the surface of a sample the interaction produces several kinds of emission including backscattered electrons having the same energy as the incident electrons, lower-energy secondary electrons, and x-rays. These emissions are detected in many scanning electron microscopes to provide information about surface topography and the distribution of chemical elements in the sample. A special adaptation of the electron microscope detects another emission, which is very low energy Auger electrons. Because these electrons have such low energy they can only escape from a very thin layer on the surface of the sample. The amount of energy they have is characteristic of the chemical elements in the sample, so analysis of an Auger spectrum identifies the composition of the sample. The scanning Auger microprobe uses a very fine electron beam to couple high lateral resolution with the high depth resolution of the Auger technique.

**PROPERTIES OF Al-Fe-Si ALLOYS.** J. I. Bennetch, Reynolds Metals Co., Richmond, VA 23261. In 1903, just 17 years after Hall and Herault independently discovered the modern electrolytic process to produce aluminum, the first rolled aluminum foil was made in France. Today, production of commercial Al foil is a major world-wide industry which centers around the use of 1XXX or 8XXX series Al-Fe-Si alloys. A primary goal of this industry is to make thinner, yet stronger, foil. It is felt this aim can be accomplished by reducing the grain size at final foil gauge, thereby strengthening foil by a grain boundary strengthening mechanism. One approach to achieve fine grain size commonly followed is a judicious variation of alloy chemistry. As a result of this study, the following observations were made. An addition of Si to Al-Fe alloys invariably led to decreased grain size. Grain boundary strengthening seemed to obey a  $D^{-1/3}$  (when  $D$  = grain size) depending on foil strength, not  $D^{-1/2}$ , as predicted by Hall and Petch. Foil strength appeared optimized for two Si/Fe regimes, one between 0.05 to 0.2 and another above about 1.0.

**CRYSTALLOGRAPHIC STUDIES OF A CELLULAR LAMELLAR INTERFACE IN Cu-4%Ti.**

Linda R. Black and Gary J. Shiflet, Dept of Materials Science, Univ. of Virginia Charlottesville, VA 22901. Our studies of the interface between ferrite and cementite in pearlite is extended to the cellular reaction in a Cu-4%Ti alloy. Hackney and Shiflet demonstrated that a direct correlation exists between lamellar interfacial structure and the growth mechanism of the pearlite colony. The cellular interfacial structure between the  $\beta$ (CuTi) and depleted matrix in Cu-Ti has been observed to contain several types of similar linear defects. Among these are misfit dislocations and direction steps. We will describe the structure of this interface through TEM imaging techniques as well as show how the habit plane configuration of the interface can be predicted on the basis of minimum interfacial interaction potential energy. (Research supported by the National Science Foundation under Grant No. DMR-83-00888.)

**OBSERVATIONS ON CORROSION TESTING IN NATURAL SEAWATER,** Frederic D. Bogar, Code 6316, Naval Research Laboratory, Washington, DC 20375-5000. Twelve years of corrosion research in natural seawater at the NRL Marine Corrosion Laboratory at Key West, Florida, are summarized. Topics to be covered include solution chemistry in localized corrosion processes, the effect of substitution of 3.5% NaCl or ASTM Ocean Water for natural seawater, and the effect of dissolved oxygen on the corrosion fatigue behavior of marine alloys.

A SEMI-AUTOMATED METHOD OF GENERATING FRACTOGRAPHIC MAPS. J. Daniel Bryant, Dept. of Materials Science, University of Virginia, Charlottesville, Va. 22901. The application of photogrammetry techniques to fractography is useful in that it assists in the identification of microstructures and their role in fracture. The interpretation of three dimensional features from two dimensional micrographs has been simplified by equipping a standard Hilger-Watts stereoscope with transducers to monitor the translations of the viewing stage, as well as the vertical motion of the light source used in reading relative heights from the fractographs. Voltage signals from the transducers are interpreted through an analog-digital converted and an ATT 6300 computer, where the readings are calibrated and normalized to yield sets of (X,Y,Z) coordinates corresponding to the features within the fracture surface. Using these coordinate files, it is possible to generate calibrated topographic maps of any fracture surface, as well as carpet plots and line profiles, using commercially available software.

FABRICATION AND SELECTED MECHANICAL PROPERTIES OF DISCONTINUOUSLY REINFORCED  $Al/Al_2O_3$  METAL MATRIX COMPOSITES. R. G. Buchheit\*, W. Ruch\* and F. E. Wawner, Department of Materials Science, School of Engineering and Applied Science, University of Virginia, Charlottesville, Virginia 22901. The feasibility of reinforcing different aluminum base alloys with discontinuous delta-alumina (Saffil) fibers using a low cost casting technique has been studied. The investigated materials include commercially available 3XX, 1XXX, 2XXX, 6XXX and 7XXX alloys. The quality of the final composite product depends strongly on processing parameters such as environment, melt temperature, alloying additions, fiber preparation, and method of fiber addition. The tensile properties of the most successfully reinforced alloys have been measured. (Research sponsored by the Virginia Center for Innovative Technology.)

AN ANALYTICAL ELECTRON MICROSCOPY STUDY OF THE THERMAL OXIDATION OF ALUMINUM-LITHIUM ALLOYS. Roger C. Dickenson & Dr. K.R. Lawless, Dept. of Materials Science, Univ. of Va., Charlottesville, Va. 22901. The addition of one to five weight percent lithium to aluminum yields alloys of reduced density and increased stiffness but they exhibit a severely increased susceptibility to thermal oxidation. The purpose of this study is to further our understanding of the oxidation processes occurring in these alloys at moderate temperatures (200-500°C). This will be accomplished by making a detailed characterization of the oxide, the oxide-metal interface, and especially the sub-surface regions of the metal at progressing stages of oxidation. The mechanisms by which microstructural and microchemical changes occur are of particular interest. Analytical electron microscopy, including convergent beam electron diffraction (CBED), will be the major tool used for this study, and we are currently developing techniques for preparing transverse sections of oxidized samples.

Observations to date show that the multi-layered oxide is primarily crystalline with  $\gamma-Al_2O_3$  and various lithium containing oxides. This is in contrast to the thin amorphous film of  $Al_2O_3$  which normally passivates aluminum alloys. The metal sub-surface shows severe depletion of lithium and substantial porosity.

(Sponsored by ALCOA. Program director: Karl Wefers)

EFFECTS OF SPECIMEN GEOMETRY ON HALL MEASUREMENTS. Bradley A. Fox\* and William A. Jesser, Dept. of Materials Science, Univ. of Va., Charlottesville, VA 22901. One method of semiconductor characterization is the van der Pauw modification of the Hall technique. In principle, the results should be independent of specimen geometry; however, due to finite contact size and contacts made away from the specimen periphery, measurements may vary with geometry. A study was performed on n-type, silicon doped gallium arsenide to determine the extent of these effects and how they might be minimized in order to allow for the use of simpler geometries.

Our experimental data shows that contact distance from the periphery has a greater effect on Hall measurements than does contact size. Also, mobility is more sensitive to contact effects than resistivity. If contacts are small, square specimen parameters are within one standard deviation of those parameters for cloverleaf specimens. For contact distances from the periphery less than one thirtieth of the specimen width, variations of less than one standard deviation were also observed. It is, therefore, not necessary to fabricate cloverleaf specimens to obtain this precision.

RECENT STUDIES OF STRESS-CORROSION CRACKING IN HIGH-STRENGTH STEELS. J. A. Hauser II and T. W. Crooker, Code 6310, Naval Research Laboratory, Washington, DC 20375-5000. Stress-corrosion cracking (SCC) is a form of spontaneous cracking which can occur in susceptible alloys under the combined effects of sustained tensile stress and a corrosive environment. The authors have conducted several recent studies of aqueous SCC in high-strength steels using precracked specimens. These studies have included the following topics: (1) influence of experimental factors on the measurement of fracture mechanics SCC threshold parameter  $K_{Isc}$ , (2) development of a novel test method for SCC in thin-section high-strength materials, and (3) effects of small-amplitude cyclic loading (ripple loading) on SCC. This presentation will include an introduction to the problem of SCC in metals and will provide an overview of current NRL studies on the subject.

DAMAGE LOCALIZATION IN ENVIRONMENT ASSISTED CRACKING OF METALS. Richard P. Gangloff\*, Dept. of Matls. Sci., Univ. of Va., Charlottesville, VA, 22901. New alloys resistant to environment assisted fracture and quantitative life predictions must be based on understanding of the interactive electrochemical, deformation and fracture processes localized at the crack tip. Recent progress is reviewed, with emphasis on the hydrogen embrittlement mechanism for corrosion fatigue of alloy steels in aqueous electrolytes. Fracture mechanics provides an approximate, but incomplete characterization of the driving forces for brittle fracture. Necessary modeling of crack electrochemistry predicts the total hydrogen production rate, as established by diffusional and convective mass transport and by strain enhanced, clean surface reactions. Crack propagation is governed by a failure criterion involving crack tip stress and adsorbed hydrogen, and which is estimated theoretically or defined experimentally with a simplified  $H_2$  environment. Crack growth models are only supported in part by critical experimentation. Corrosion fatigue crack paths are either along prior austenite or tempered martensite boundaries. Surprisingly, microstructural variables are less important than chemical or mechanical factors. Directions for future research are identified.

DEFECTS IN METALS, P. Jena\*, S. N. Khanna\* and B. K. Rao\*, Dept. of Physics, Virginia Commonwealth Univ., Richmond, Va. 23284. Defects in materials not only break the long range periodicity of the crystals but also affect their mechanical and electronic properties. A fundamental understanding of the interaction between the defect and its host metal atoms involves studies of the host electron response to the defect. Using state-of-the-art theoretical techniques, we have been studying the interaction of defects such as hydrogen, helium, and other impurities as well as vacancy and vacancy clusters in simple, noble, and transition metal hosts. Examples of our studies will be presented to illustrate how the structural and electronic properties are affected due to point defects as well as defect complexes.

MICROSTRUCTURAL INVESTIGATIONS OF GAP IN SI-GE ALLOYS. K. Owusu - Sekyere\*, F. D. Rosi\*, W. A. Jesser, Department of Materials Science, University of Virginia, Charlottesville, Va. 22901. Si-Ge binary and ternary alloys have been used as a source of space power. Additions of GaP to the binary alloy have been reported to reduce the thermal conductivity and thus improve the figure of merit for power generation. Combined SEM and TEM analyses have been used to determine the GaP distribution and the appearance of second phases to help explain the role of GaP in the Si-Ge thermoelements. (Supported by General Electric Company and the Virginia Center for Innovative Technology.)

A STUDY OF CONDUCTING POLYMERS, B. K. RAO\*, P. Jena\* & S. N. Khanna\*, Dept. of Physics, VA Commonwealth University, Richmond, VA 23284

Some conjugated organic polymers have caught the attention of scientists and industrialists lately due to their novel properties. When suitably doped, they show dc conductivity, paramagnetism, photo-electric and piezo-electric properties. Potential uses can be found for these polymers in producing light-weight, low cost, high efficiency batteries, solar cells, heat and pressure sensors for missile guidance systems, electrochromic displays for computers and many others. We conduct theoretical research on the electronic structure of two such polymers - polyacetylene and para p-phenylene. We model the polymers with a computer using ab initio SCF-LCAO-MO procedure and study the energies, charge and spin density distributions at various isomeric conformations of these polymers. Results from these studies explain the mechanisms for isomerization, helix formation and conduction in these polymers.

THE DOMAIN DIELECTRIC SPECTROSCOPY AS A TOOL TO STUDY PHASE NUCLEATION PROCESSES. C. D. Ross, C. C. Huang and R. E. Barker, Jr., Dept. of Materials Science, University of Virginia, Charlottesville, VA. 22901. Conventional (frequency domain) dielectric spectroscopy (FDDS) is very useful for studying molecular interactions in systems which are in equilibrium but it is not usually convenient, or in some cases feasible, to investigate transient processes by FDDS. A major advantage of time domain dielectric spectroscopy (TDDS) is that many types of transient phenomena can be studied. As a point in question, the use of TDDS for the investigation of the kinetic processes associated with the nucleation and growth of a second phase in an initial phase will be discussed. As a model system some results for the phenol-water system will be presented and the use of the technique for the study of phase separation in polymer blends and for the diffusion of plasticizer in polymers will be considered. (Supported by Grants USAFOSR 82-0290C and NASA-NAG 1-419.)



## Medical Sciences

THE EFFECT OF (-)-MORPHINE ON ENDOGENOUS OPIOID PEPTIDE RELEASE INTO CANINE CEREBROSPINAL FLUID (CSF) AND PLASMA. Michael L. Adams\*, D.L. Morris\*, and W.L. Dewey, Department of Pharmacology and Toxicology, Medical College of Virginia/Virginia Commonwealth University, Richmond, Virginia 23298-0001. Morphine,  $\beta$ -endorphin, [met]enkephalin, [leu]enkephalin, and dynorphin 1-13 were quantitated in canine CSF and plasma that were sampled one hour after a 10 mg/kg s.c. dose of (-)-morphine SO<sub>4</sub> or an equimolar dose of (+)-morphine HBr. Antinociception and morphine-induced signs were also quantitated. Control levels for each dog were taken one week earlier at the same time of day after saline injections. Plasma  $\beta$ -endorphin and enkephalin levels, CSF and plasma levels of (-)-morphine, antinociception, and morphine-induced signs were all significantly increased by (-)-morphine. CSF levels of opioid peptides were not altered by (-)-morphine. No effects were observed after (+)-morphine. We conclude that morphine stereoselectively increases antinociception, morphine-induced signs, and plasma levels, but not CSF levels, of some endogenous opioid peptides in dogs. (Supported by U.S.P.H.S. Grant DA-01647 and T32-DA-07027.)

METABOLISM OF THE N-GLUCOSIDES OF PHENOBARBITAL. Bruce E. Agriesti and William H. Soine, Dept. Medicinal Chem., Lorne K. Garrettson, Dept. Pharmacy and Pharmaceutics, Va. Commonwealth Univ., Richmond, Va. 23298 & Phyllis J. Soine, Dept. Chem., Randolph-Macon Col., Ashland, Va. 23005. The N-glucosylation of phenobarbital leads to the formation of two diastereomers. Each diastereomer was tested individually in mice at 1000 mg/kg (ip) for their ability to disrupt motor activity. Both diastereomers were found to be inactive. Urine was collected from the mice administered the diastereomers and analyzed by HPLC for released phenobarbital. Both phenobarbital and p-hydroxy-phenobarbital were detected in the urine. The identity of these excretion products were further characterized by GC/MS. Phenobarbital was not released from the conjugates under acidic or basic conditions, suggesting deconjugation was an enzymatic process. It was observed that both diastereomers were rapidly excreted in the urine with over 90% being excreted in the first 12 hours. After intraperitoneal dosing of mice with phenobarbital for 5 days no formation of the major diastereomer detected in humans was detected. (Supported by the American Epilepsy Foundation and the A.D. Williams Student Summer Research Fellowship)

SUPPLEMENTARY DIETARY BRANCHED-CHAIN AMINO ACID (BCAA) AND TUMOR GROWTH. L. Baron\*, P. Baron\*, W. Chan, F. White\*, and W.L. Banks, Jr., Dept. of Biochem. and Massey Cancer Ctr., MCV/VCU, Richmond, VA. 23298. This study examined whether BCAA has an anabolic effect on tumor growth and/or host metabolism. Male Fischer 344 rats with MCA fibrosarcoma were fed either the control(C) or the experimental(E) diet containing 4X BCAA of that of C. At days 0,3,6, and 9, five rats from each group were killed and *in vivo* <sup>14</sup>C-tyrosine and <sup>3</sup>H-thymidine uptakes measured in the acid insoluble fractions (AI) of muscle, liver and tumor. In addition, cell cycle kinetics of tumor cell suspensions were assessed. The latter showed that the diet did not result in alteration in the % of hyperdiploid cells of the tumors from both groups. From days 3 to 9, the % of diploid cancer cells in both groups increased significantly. In skeletal muscle and tumor tissues, there were significant decreases in <sup>14</sup>C incorporation into the AI at day 9 as compared to day 0. The <sup>3</sup>H uptake results indicated that when tumor size was increased, protein (<sup>14</sup>C) and DNA (<sup>3</sup>H) precursor uptakes into these host tissues were decreased. As for the tumor tissue samples, the <sup>3</sup>H incorporations were decreased at days 6 and 9, but the <sup>14</sup>C incorporation showed a decrease only at day 9 for both groups. No anabolic effects on tumor growth could be attributed to elevated dietary intakes of BCAA using the parameters studied. (Supported by A.D. Williams Fluid Fd. for Res. and NIH CA 16059).

CALCULATION OF  $K_i$  AND INHIBITOR TYPE FROM  $I_{50}$ . R.B. Brandt, Dept. of Biochem. and Massey Cancer Ctr., VA Commonwealth Univ., Richmond, VA 23298. Drugs frequently act by inhibiting enzyme activity. A convenient method for reporting inhibitor effects uses the concentration of inhibitor for 50% activity inhibition ( $I_{50}$ ). The type of inhibition (competitive, non-competitive or uncompetitive) and the  $K_i$  (a kinetic measure of the dissociation constant of the enzyme-inhibitor complex) frequently are important characteristics to determine. The relationship between  $K_i$  and  $I_{50}$  has been treated elsewhere, however, the implications of the relationship between simple correlations for determining both  $K_i$  and type of inhibition is not clearly shown. The importance of determination of  $K_i$  from data involving such simple values as percent inhibition of an enzyme reaction, includes use of data from different laboratories to determine kinetic parameters and the type of inhibitor as well as additional constants for modeling to design new inhibitor molecules. (Supported by funds from NCFR.)

PARTIAL CHARACTERIZATION OF MACROPHAGE AMOEBICIDAL FACTORS. S.F. Cleary and F. Marciano-Cabral, VA Commonwealth Univ./MCV, Richmond, VA 23298. Macrophage protozoacidal activity has been described primarily with respect to intracellular parasites. Our investigations have sought to determine the mechanism of macrophage-mediated cytolysis of the extracellular amoeba, Naegleria fowleri. Murine peritoneal macrophages were coincubated with  $^3\text{H}$ -Uridine labeled amoebae. Percent specific release of label served as an index of cytolysis. In contrast to resident or elicited macrophages, those activated with Corynebacterium parvum or Bacille Calmette-Guerin (BCG) mediated significant cytolysis of amoebae. Amoebicidal and tumoricidal activity were expressed to the same degree. Amoebicidal activity was oxygen-independent but dependent on RNA and protein synthesis. Amoebicidal activity was inducible by target cell binding or stimulation with LPS. Conditioned medium from LPS-stimulated macrophage cultures contained a heat stable ( $56^\circ\text{C}$ , 30 min) activity which coprecipitated with tumoricidal activity by ammonium sulfate. Results suggest amoebicidal and tumoricidal activity may be mediated via similar mechanisms. (Supported by VA Power Company and NIH Training Grant CA 09210).

STATISTICAL SEPARATION OF CANCER, HEART AND CONTROL PATIENTS: ARE DISCRIMINANT FUNCTIONS PREDICTIVE OF INDIVIDUALS IN GROUPS? Germille Colmano, L.M. Evans,\* and C.D. Sargent,\* VA-MD Regional College of Veterinary Medicine, VPI & SU, Blacksburg, VA, 24061. Three pools of amino acids, separated by absorption spectrophotometry, indicated markers in absorption spectra of blood plasma, capable of separating individuals susceptible /resistant to some diseases. From a data base we separated male/female, normal (technicians, male students with/without exercise, females (mostly type A-coronary prone and some B psychological behavior profile), abnormal (different conditions), pregnant, heart, cancer (different types), cancer of the stomach, and ulcer patients. Cluster analysis proved too weak as a method of separation and indicated group separation with overlapping. Group belonging and separation by discriminant function indicated that even with different groups overlapping the cancer patients as a group could be clearly separated from all the other groups. This would indicate a certain predictability of individuals belonging in a cancer group classification. Presently, we are waiting for confirmation of a prediction using an enlarged data base and more specific criteria for individual classification.

KAPOSI'S SARCOMA IN AIDS. E. Dutz-Kohout, McGuire VA Medical Center, Richmond, VA 23249 and the Medical College of Virginia, Richmond, VA 23298. A 29 year old man with HLTV III infection was admitted with end-stage renal disease and died in cardiopulmonary arrest. Widespread CMV infection of the lung caused his demise. Kaposi's disease was diagnosed from a biopsy of the toes and variously interpreted due to the subtlety of the lesion. The disease eventually became widespread. No characteristic body habitus or weight loss was noted in the patient, nor have there been any abnormal immunological parameters. There was an absent spermatogenesis. The diagnostic implications on histology and the different diagnostic features of epidemic, classic African and renal transplant Kaposi's disease will be discussed.

THE EFFECTS OF STREPTOZOTOCIN DIABETES ON PHENYLETHANOLAMINE N-METHYLTRANSFERASE IN THE RAT BRAIN. Krista J. Fischer & Jennifer K. Stewart, Dept. of Biol., Va. Commonwealth Univ., Richmond, Va. 23284. Recent evidence suggests that adrenergic neurons in the brainstem and hypothalamus are important in the regulation of endocrine and cardiovascular function and in the response to stress. Since abnormalities of several of these functions are observed in diabetic subjects, we investigated the effects of Streptozotocin-induced diabetes on the activity of the enzyme that converts norepinephrine to epinephrine (phenylethanolamine N-methyltransferase, PNMT) in the brainstem and hypothalamus of the rat. Diabetes of one month duration was associated with approximately a 2-fold increase in brainstem PNMT activity ( $P < 0.0001$ ), and chronic insulin treatment partially reversed the effects of the diabetes ( $P < 0.01$ ). Enzyme activity exhibited a positive ( $P < 0.001$ ) correlation with plasma glucose ( $r = 0.51$ ). Diabetes had no apparent effect on PNMT activity in the hypothalamus. These findings are the first to suggest that the metabolic stress of experimental diabetes alters PNMT activity in the medulla/pons.

NOVEL STRATEGIES FOR INDUCTION OF MACROPHAGE ANTI-TUMOR ACTIVITY. William S. Futch, Jr., J. Michael Shaw and Lawrence B. Schook, Dept. of Microbiology and Immunology, Medical College of Virginia, Virginia Commonwealth University, Richmond, VA and Alcon Laboratories, Fort Worth, TX.

A novel method has been developed for the selective delivery of a lipophilic immunomodulator to macrophages (MØ) which results in the induction of anti-tumor activity. The method consists of using acetylated low-density lipoprotein (acetyl-LDL) to deliver the lipophilic immunomodulator, muramyl tripeptide phosphatidylethanolamine (MTP-PE), to MØ via a scavenger lipoprotein-receptor pathway. Cytostatic activity was induced in thioglycolate-elicited MØ toward B16F10 melanoma cells with 25 µg acetyl-LDL protein containing 2.5 µg of bound MTP-PE (~40 molecules/particle). The induction of MØ cytostatic activity by acetyl-LDL:MTP-PE was not reduced by excess liposomes which were endocytosed by the MØ. Interaction of the acetyl-LDL:MTP-PE complex with thioglycolate-elicited MØ was monitored using the fluorescent dye DIL, which remained tightly associated with the lipoprotein-immunomodulator complex. The binding of acetyl-LDL:MTP-PE to MØ showed specificity in that negligible competition was observed in the presence of excess native LDL or liposomes.

THE BINDING OF AN ANTI-LYMPHOCYTE FUNCTION-ASSOCIATED ANTIGEN-ONE (LFA-1) MONOCLONAL ANTIBODY (RH1-38) TO LYMPHOKINE ACTIVATED KILLER (LAK) CELLS INHIBITS THEIR CYTOLYTIC CAPACITY. Angus J. Grant\*, R.E. Hall\*, R.E. Merchant\*, (Spon: M.M. Sholley) Dept. of Anatomy and Div. Hematology-Oncology, Dept. of Medicine, MCV-VCU, Richmond, VA 23298

A mouse monoclonal antibody (McAb) (RH1-38) which recognizes an epitope on the  $\beta$  chain of LFA-1 was used to explore the function and expression of LFA-1 on LAK cells. This McAb blocks cytotoxicity mediated by natural killer (NK) cells and cytotoxic T lymphocytes (CTL). LAK cells generated by the incubation of human peripheral blood lymphocytes (PBL) in 1000 U/ml human recombinant interleukin-2 (Cetus Corp.) (rIL-2) for 5 d. mediated reduced lysis against  $^{51}\text{Cr}$ -labeled Daudi cells exposed to RH1-38 McAb or F(ab')<sub>2</sub> fragment. Controls consisting of NS-1 ascites supernatant or mouse IgG had no effect. Indirect immunofluorescence studies revealed that LFA-1 expression was enhanced on LAK populations over PBL cultures. These studies demonstrate that LFA-1 is an important surface molecule of LAK cells, that homology to NK and CTL lytic mechanisms exists, and that enhanced LFA-1 expression may be important in LAK toxicity.

POTENTIAL INHIBITORS OF CARBOXYLATE-ACTIVATING LIGASES. Neile A. Grayson\* and Richard B. Westkaemper\*, Department of Medicinal Chemistry, School of Pharmacy, MCV-VCU, Richmond, Va 23298. A series of adenosine 5'-alkylmonophosphates (R-O-AMP), where R= methyl, ethyl, propyl, butyl, and hexyl, were designed and synthesized as potential bisubstrate analog inhibitors of the enzyme S-acetyl coenzyme A synthetase (EC 6.2.1.1). This enzyme produces acetyl coenzyme A, AMP and pyrophosphate from acetate, coenzyme A and ATP. The inhibitors are stable analogs of the reactive acyl adenylate intermediate which is formed by the enzyme. The inhibitors were evaluated in a spectrophotometric assay based on the formation of AMP. Compounds where R=methyl, ethyl, and propyl were found to be potent inhibitors of S-acetyl coenzyme A synthetase with dissociation constants in the micromolar range. Compounds where R=butyl and hexyl were found to be weak inhibitors with dissociation constants in the molar range.

EFFECT OF HEPARIN AND STEROIDS ON PROLIFERATION OF HUMAN ENDOTHELIAL CELLS IN VITRO. S.A. Gudas, M.Y. Kalimi & M.M. Sholley, Depts. of Anatomy and Physiology, VA Commonwealth Univ., Richmond, VA 23298. It has recently been reported that angiogenesis, which involves migration and proliferation of endothelial cells (EC) from blood vessels, can be inhibited in vivo by combined treatment with heparin and selected steroids. We have begun studies to determine the effect of heparin and steroids on proliferation of EC derived from human umbilical veins and propagated in vitro. Heparinized (90 µg/ml) culture media were supplemented with dexamethasone (5,1,0.5 & 0.1 µM), hydrocortisone (20,10,5 & 1 µM) and dehydroepiandrosterone (DHEA) (50,20,10 & 5 µM). Control and experimental media contained dimethylsulfoxide (DMSO) at a concentration of 0.1%. Media were added to second passage cultures at 2 days, the beginning of the log phase of growth, and cell number was assessed at 7 days. All doses of dexamethasone increased the cell numbers significantly with respect to DMSO controls, but a dose-response relationship was not observed. All doses of hydrocortisone and DHEA were associated with nonsignificant elevation of cell numbers. DHEA caused changes in cellular morphology not seen with the other steroids. Whether other steroids or different doses might inhibit proliferation of EC, as anticipated from in vivo observations, remains to be determined. (Supported by ACS grant IN-105K).

MORPHOGENESIS OF THE GLIA LIMITANS IN THE DEVELOPING OPTIC NERVE OF THE HAMSTER EMBRYO. Thomas M. Harris, Dept. of Anatomy, Va. Commonwealth Univ., Richmond, VA, 23298. The glia limitans (peripheral glial mantle of Fuchs) consists of a continuous layer of astrocytes and astrocytic processes between the basal lamina of the pia mater and the peripheral neural tissue (Cohen, '70). It is also thought to be a component of the "blood-brain" barrier, (Dunn & Wyburn, '72). Using the electron microscope, we have described for the first time the events involved in the morphogenesis of the glia limitans. There are at least three stages in the process, one of which may represent a unique morphogenetic mechanism. As the initial optic stalk cells (primitive astrocytes) are displaced from the nerve periphery by invading nerve fibers, the integrity of the glia limitans is maintained by a network of glial processes that are attached to the parent astrocytes by long slender cytoplasmic strands which may be several microns long. We have named these previously undescribed structures gliopodia. This and the other phases will be described in greater detail.

IMMUNOCHEMICAL EVIDENCE FOR MULTIPLE STEROID-INDUCIBLE HEPATIC CYTOCHROMES P-450 IN THE RAT. K.A. Hostetler, S.A. Wrighton,\* and P.S. Guzelian.\* Depts. of Pharmacol. & Med., Med. Col. of Va./Va. Commonwealth Univ. Richmond, VA. 23298. Structurally and functionally related steroid-inducible hepatic cytochromes P-450 have been identified in the rat (P-450p), the rabbit (LM3c), and man (HLp). We prepared a monoclonal antibody (1G8) that reacts with purified P-450p but not with HLp. On immunoblots, 1G8 reacted with two proteins in liver microsomes from untreated male rats, one co-migrating with P-450p and a second faster migrating protein. No 1G8-reactive proteins were detected in untreated female microsomes. A second monoclonal antibody, 13-7-10, which reacts with HLp but not P-450p, reacted with sex-specific proteins of different apparent molecular weights in microsomes from untreated male and female rats. Quantitative immunoblots of microsomes isolated from induced female rats revealed that triacetyloleandomycin (TAO) was the most efficacious inducer of 1G8-reactive proteins followed by dexamethasone (DEX), chlordane (CD), pregnenolone-16 $\alpha$ -carbonitrile (PCN), and 2,4,2',4'-PCB (PCB). In contrast, 13-7-10-reactive proteins were induced most strongly by DEX, only moderately by TAO and PCN, weakly by CD, and not at all by PCB. We conclude that there are multiple steroid-inducible cytochromes P-450 expressed discoordinately in rat liver. Supported by NIH grant AM 18976.

DETECTION OF TUMOR SPECIFIC GANGLIOSIDES IN COLORECTAL CARCINOMA CELLS USING ANTI-SIALYL OLIGOSACCHARIDE ANTIBODIES. Kevin L. Law\* & David F. Smith, Dept. of Biochemistry & Nutrition, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. The expression of the colorectal cancer associated antigen, the sialyl Lewis a ganglioside, is dependent on the Lewis blood type of the patient. Individuals having this form of cancer but who have either Lewis b or Lewis - blood type will express the antigen either in very reduced quantities or not at all. The presence of oligosaccharide structures related to the sialyl Lewis a antigen, but not Lewis blood group dependent, were detected in the SW1116 colorectal carcinoma cell line. Ganglioside-derived oligosaccharides were characterized using rabbit antisera directed against human milk sialyl-oligosaccharides. Previously undetected ganglioside structures identified in this cell line may prove to be better cancer markers than the sialyl Lewis a antigen since their presence is not dependent on the Lewis blood group genotype.

TIME COURSE FOR THE EFFECTS OF SOMAN ON MOUSE BRAIN CHOLINERGIC FUNCTION. Dwayne M. Little\*, H.L. Tripathi\*, A.R. Szakal\* and W.L. Dewey. Department of Pharmacology/Toxicology, Medical College of Virginia, Richmond, VA 23298-0001.

The effects of soman on acetylcholine (ACh) and choline (Ch) levels and turnover rate of ACh in mouse whole brain and brain areas were investigated. ACh, Ch and ACh turnover were quantitated at 1, 5, 10, 15, 30, and 60 minutes by high performance liquid chromatography with an electrochemical detector. Mice were injected (i.v.) with 80  $\mu$ g/kg of soman or vehicle and  $^3$ H-Ch was injected (i.v.) two minutes prior to sacrifice by microwave irradiation to the head. Eighty  $\mu$ g/kg of soman significantly increased ACh levels at 10 and 15 minutes and Ch level at 30 and 60 minutes, whereas ACh turnover was decreased at 5, 10, 30 and 60 minutes. ACh levels increased significantly in hippocampus, corpus striatum and cortex and Ch levels in cerebellum, midbrain, hippocampus and cortex brain regions. Turnover rate was decreased in medulla pons, midbrain, hippocampus and corpus striatum. The inhibition of acetylcholinesterase caused by soman had a greater effect on acetylcholine turnover than on acetylcholine or choline levels. Thus, this decrease in turnover may be a compensatory response to attempt to maintain cholinergic function within normal levels. (Supported by U.S.A.M.R.D.C. Contract DAMD 17-82-C-2174).

THE BIODISPOSITIONAL EFFECTS OF AMMONIUM CHLORIDE TREATMENTS ON ORALLY OR INTRAVENOUSLY ADMINISTERED  $^3\text{H}$ -PCP. James E. Lyddane\*, Brian F. Thomas\*, and Billy R. Martin. Department of Pharmacology and Toxicology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Va. 23298.

Phencyclidine (PCP) abuse occurs by various routes of administration, and often requires extensive treatment for recovery. Studies were done to determine alterations of PCP's effects and biodisposition by urine acidification (2.5 meq  $\text{NH}_4\text{Cl}$ /kg administered p.o. hourly after PCP, with a six treatment maximum). Urinary pH decreased to 5.5 after 7 hrs. The treatment group's motor performance (rotarod test) revealed data with area under the curve (AUC) values of 7, 10, and 17% less than the corresponding water-treated rats, after oral PCP at 10, 25, and 50 mg/kg respectively. Similarly, the treatment groups dosed i.v. with 2.5, 5, 10, and 15 mg PCP/kg had AUC's of 6, 14, 32, and 19% less than the controls, respectively. Correspondingly, treatment group brain levels of  $^3\text{H}$ -PCP decreased by 5% or 32%, while urinary excretion increased by 52% or 36%, after 50 mg PCP/kg (i.v.), or 10 mg PCP/kg (p.o.) respectively. Decreased gastric absorption or enhanced urinary excretion may account for the  $\text{NH}_4\text{Cl}$ 's effects on the oral PCP; however since intravenously administered PCP showed similar responses, decreased gastric absorption seems unlikely. These findings demonstrate that rigorous  $\text{NH}_4\text{Cl}$  treatment results in only modest effects on PCP intoxication. Supported by NIDA grant DA-02396.

THE ROLE OF ENDOGENOUS OPIOIDS IN ANTINOCICEPTION AND OTHER CLINICAL SYNDROMES. Dale L. Morris\*, E.C. Myer\*, R. Zimmerman\*, M.L. Adams\*, and W.L. Dewey, Departments of Pharmacology, Neurology, and Neurosurgery, Virginia Commonwealth University, Medical College of Virginia, Richmond, Virginia 23298-0001

Previous studies have indicated that endogenous opioid peptides play an important role in pain perception, stress, and the regulation of respiration in animals. Methodology was developed to quantitate immunoreactive  $\beta$ -endorphin in cerebrospinal fluid (CSF) and other body fluids in an attempt to determine the role of these substances in various human conditions. We have quantitated the level immunoreactive  $\beta$ -endorphin in adults with severe head injuries and children having severe apneic episodes (or other respiratory dysfunctions). Our findings suggest that elevated levels of immunoreactive  $\beta$ -endorphin detected early in the course of injury may indicate a better outcome for severely head injured patients. Levels of immunoreactive  $\beta$ -endorphin found in children with severe apnea, or in those who were diagnosed as being at risk for Sudden Infant Death Syndrome, were significantly higher than in control children. These results cause us to suggest that endogenous opioid peptides play an important role in various clinical syndromes. (Supported by Grants T32 DA-07027 and DA-01647).

SYNTHESIS AND DISCRIMINATIVE STIMULUS PROPERTIES OF METHCATHINONE. N. Naiman\* and R. A. Glennon\*, Dept. Medicinal Chemistry, MCV/VCU, Richmond, Va 23298. S(-)-Cathinone, an active ingredient of the leaves of the plant *Catha edulis* (khat), has central stimulant properties similar to those of amphetamine (1). The only structural modification of amphetamine that retains stimulant activity is monomethylation of the terminal amine to give methamphetamine (2). If amine methylation of cathinone (3) results in retention of stimulant activity, this would lend support to the hypothesis that 1 and 3 produce their stimulant activity via a common mechanism. Oxidation of ephedrine using  $\text{CrO}_3/\text{H}_2\text{SO}_4$  gave (+)N-methylcathinone (methcathinone) (4) in one step. Comparison of (+)1-(+)4 in a drug discrimination paradigm using rats trained to 1.0 mg/kg (+) amphetamine sulfate using a VI 15-sec schedule of reinforcement resulted in stimulus generalization in each case, suggesting that these agents produce common stimulus effects in the rats. The  $\text{ED}_{50}$  values are (+)1 0.71, (+)2 0.49, (+)3 0.71, and (+)4 0.37 mg/kg. Preliminary data indicate that (+)4, like the other agents, is also a potent locomotor stimulant in mice. Because the one structural change that is tolerated in 1 is also tolerated by 3, and because all of the agents produce the same stimulus, this supports the idea that they may work via a common mechanism.

HTLV-III ANTIBODY TESTING: ELISA AND WESTERN BLOT RESULTS WITH CLINICAL CORRELATION. L. A. Oakley,\* M.R. Escobar, & L. G. Kaplowitz, Med. Col. of Virginia, VA. Commonwealth Univ. Richmond, Virginia 23298. Sera from 526 persons were assayed for HTLV-III antibodies (Ab) by Abbott ELISA (E) and Western Blot (WB). Of those tested, 100 (19%) were E+ and were categorized by p24 & p41 protein banding patterns on WB: G1-p24(-) & p41 (-); G2-p24(+) & p41(-); G3-p24(-) & p41(+); G4-p24(+) & p41(+). Mean ELISA ratios (MER), the mean of the ratio of test result to control, were calculated for each of the above groups, & clinical data noted:

	G1	G2	G3	G4
Number	19	24	4	53
Risk Factors	12	21	4	51
ARC	3	12	0	19
AIDS	3	4	2	6
MER	3.49	8.73	10.37	12.02

The MER was 4.2 for females; 10.2 for males; 9.2 for those with risk factors for acquisition of HTLV-III compared to 2.9 for those with no known risk factors; & 8.14 for AIDS patients. The majority of seropositive persons who are WB+ have the p24 band present; it is unusual for only the p41 band to be present. Persons with risk factors have higher MER than those without risk factors who are E+.

SYNTHESIS AND CHARACTERIZATION OF N-GLUCOSIDES OF BARBITURATES. Bruce W. Overton and William H. Soine, Dept. of Medicinal Chem., Va. Commonwealth Univ., Richmond, Va. 23298, & Phyllis J. Soine, Dept. of Chem., Randolph-Macon Col., Ashland, Va. 23005. When glucose is coupled to phenobarbital or amobarbital, diastereomers will be formed. The diastereomers of the N-glucosides of amobarbital and phenobarbital, and the N-glucoside of barbituric acid were synthesized by coupling the persilylated barbiturate with glucose pentaacetate in the presence of tin tetrachloride followed by hydrolysis of the acetates with sodium methoxide. The diastereomers were purified using HPLC (C-18, 20% acetonitrile / 80% 0.05M ammonium acetate buffer) and characterized by UV, proton and carbon NMR, MS, optical rotation and CHN. During characterization of these diastereomers with NMR, two syn and anti conformational isomers could be detected. Analysis of the persilylated N-glucoside conjugates using megabore capillary gas chromatography suggested that the conformers could be differentiated during analysis. Attempts to synthesize the N-glucose conjugates of mephobarbital and metharbital were unsuccessful due to exclusive O-coupling instead of N-coupling. (Supported by the Epilepsy Foundation of America and an A.D. Williams Student Summer Research Fellowship)

HISTOCHEMICAL STUDY OF ACROSOME MODELING IN THE GUINEA PIG SPERMATID USING DIPEPTIDYLPEPTIDASE II AS A MARKER. N.O. Owers, Dept. of Anat., MCV-VCU, Richmond, VA 23298, & J.K. McDonald\*, Dept. of Biochem., Med. Univ. of South Carolina, Charleston, SC 29425. Dipeptidylpeptidase II (DPP II) is visualized histochemically in formalin fixed 16u cryostat sections of the developing guinea pig testis and epididymus. The sections are incubated in a mixture containing 1mM specific peptide methoxynaphthylamide substrate and Fast Blue B 1mg/ml. The presence of the enzyme is indicated by the development of a bright red color in 10-30 minutes. The tissues are mounted in glycerol jelly and examined by light microscopy. Enzyme activity was entirely absent in tissue sections taken from immature guinea pigs, partially present in tissue sections from guinea pigs weighing 250-350g, and only in the fully mature animals, 500-850g, was enzymatic activity observed in all the testis and epididymal tubules. A DPP II positive granule present in a spermatid enlarges to form a flattened sphere, which then partially surrounds the sperm nucleus and forms a cap filled with enzyme in the head region. These findings show that (a) DPP II is present as an active (lysosomal) protease during spermiogenesis, (b) activity arises in association with sexual development, and (c) the acrosome is formed by lysosome remodeling in the spermatid.



ANALYSIS OF INTRAMOLECULAR HYDROGEN BONDING OF 5-HT<sub>1A</sub> RECEPTOR AGONISTS USING NUCLEAR MAGNETIC RESONANCE. E. Pierson\*, A. E. Hauck\*, R. Westkaemper\*, R. A. Glennon\*, Dept Med Chem, MCV/VCU, Richmond, VA 23298. 8-Hydroxy-2-(di-n-propylamino)tetralin (8-OH DPAT; 1) is a site selective serotonin (5-HT), i.e. 5-HT<sub>1A</sub>, agonist. Several ring-open analogs of 8-OH DPAT were synthesized and their affinity for central 5-HT<sub>1A</sub> binding sites examined using [<sup>3</sup>H]8-OH DPAT as the radioligand. N,N-Di-n-propyl-2-hydroxyphenethylamine (2), for example, was found to be 100-fold less potent ( $K_i=400$  nM) than 8-OH DPAT ( $K_i=3$  nM); subsequent studies focused on why the ring-open analogs were so much less potent than 8-OH DPAT at 5-HT<sub>1A</sub> sites. 8-OH DPAT is a relatively rigid molecule whereas the side chain of 2 is less conformationally restricted. As a consequence, the possibility exists that 2, but not 8-OH DPAT might undergo intramolecular H-bonding. The proton and carbon 13 NMR spectra of 2 were examined to obtain evidence for such an effect. H-bonding shifts proton signals downfield, and shifts the signals of the carbon atom  $\beta$  to the amine, upfield. The phenolic proton signal of 2 showed a downfield shift of 4 ppm when compared to phenol, the  $\beta$  carbon signals were shifted 1.2 ppm upfield compared to the O-methyl ether of 2. 8-OH DPAT does not intramolecularly H-bond, so the intramolecular H-bonding of 2 may explain its decreased affinity for 5-HT<sub>1A</sub> sites.

RECONSTITUTION OF IMMUNE RESPONSIVENESS THROUGH GENE TRANSFER IN GENETICALLY DEFECTIVE MICE. J.K. Pullen, E. Eustis-Turf and L.B. Schook, Dept. of Microbiology and Immunology, MCV-VCU, Richmond, VA.

C57B1/6(H-2<sup>b</sup>) mice fail to express I-E molecules because of a deletion in their E $\alpha$  gene and thus are unable to respond to I-E restricted antigens. Experiments in our laboratory have permitted the development of a model for studying the differentiation *in vitro* of antigen presenting M $\phi$ . Using a modified calcium phosphate protocol, we have transfected C57B1/6 marrow with a cloned E $\alpha$  gene and detected the I-E molecule on the surface of bone marrow derived M $\phi$  (BMDM) by using an anti-I-E monoclonal antibody in both RIA and immunoprecipitation assays. BMDM expressed the I-E product maximally at 5d of differentiation after which the expression declined. Furthermore, the expression of the I-E molecule on BMDM was dependent upon gamma interferon. Expression of the I-E molecule was also detected by allogeneic T cells. Transfected BMDM were compared to CB6F<sub>1</sub> BMDM for their ability to stimulate C57B1/6 T-cells and were found to be equally effective. The ability of the BMDM to express membrane associated IL-1, as detected by the T cell line D10.G41, was not affected by the transfection process. We are using this system to understand the expression and regulation of class II MHC gene.

HISTOFLUORESCENCE OF AUTONOMIC NERVES IN BLOOD VESSELS OF DIABETIC RATS. J. Renfro and J. Hart. Biology Dept. George Mason Univ. Fairfax, VA 22030. The norepinephrine (NE) content of tail arteries (TA) from 8 wk streptozotocin (SZ) diabetic rats has previously been reported to be significantly less than that of age-matched controls, suggesting that there may be a loss of adrenergic nerves in diabetic vessels. In the current studies, the glyoxylic acid histochemical fluorescent method was used to visualize adrenergic neurons in the TA and inferior vena cava (IVC) from 8-10 week SZ diabetic rats and controls in order to determine if innervation density changes during diabetes. Fluorescent networks of nerve fibers were visible in both the TA and IVC. Innervation density was assessed by counting the number of fibers intersecting a standard grid placed over photographs of the vessels. No sig. differences between controls and diabetics were found in either the TA or IVC. This suggests that the reduction in NE content of diabetic vessels is not associated with an actual loss of nerves at this stage of diabetes, but may be dependent on other changes which can not be detected by this method of visualizing adrenergic nerves. (Supported by a grant from the Virginia Affiliate of the Am. Heart Ass.)



THE EFFECTS OF COUNTERIONS ON DNA CONFORMATION IN GEL PHASE. Alfred J. Richard & Richard B. Westkaemper Department of Medicinal Chemistry, Virginia Commonwealth University, Richmond, Va. 23298. Equilibrium ultracentrifugation of high molecular weight DNA at moderate centrifuge speeds leads to the formation of gel at the bottom of the centrifuge cell. The swelling pressures of the gels are strongly affected by ionic strength of the medium and by polyvalent counterions in the medium. Scaled particle theory applied to the DNA gels gives values of the effective particle length and particle radius of the DNA. Different models for DNA conformations in the gels were required for the monovalent, the divalent and the tetravalent cations used in this study. (Supported by the Grants-in-Aid Program for Faculty of Virginia Commonwealth University.)

VITAMIN C AND LYMPHOCYTOPENIA. John H. Richardson and Cynthia Dorr,\* Dept. of Biol., Old Dominion Univ., Norfolk, Va. 23508. The results of previous research with stressed mice have shown that large daily doses of vitamin C maintained significantly higher levels of plasma adrenal cortical hormones than stressed control animals who received no vitamin C. The results of our research with stressed mice showed that large daily doses of vitamin C induced severe lymphocytopenia as would be expected if the plasma corticosteroid levels remain high. The placebo animals recovered from lymphocytopenia on the sixth day of the experiment and none of the animals in this group fell below the control lymphocyte mean of 51.0 for the remainder of the experiment. All of the vitamin C animals remained below the control lymphocyte mean for the duration of the experiment. It appears that vitamin C may be immunosuppressive when stress is present.

EFFECT OF ACUTE DIISOPROPYLFLUOROPHOSPHATE (DFP) EXPOSURE ON  $^3\text{H}$ -( $\pm$ )NICOTINE BINDING TO MOUSE BRAIN HOMOGENATE. Joseph A. Scimeca\*, and Billy R. Martin. Department of Pharmacology and Toxicology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Va. 23298.

Scatchard analysis of  $^3\text{H}$ -( $\pm$ )nicotine binding to mouse brain homogenate (minus cerebellum) produced a curvilinear plot that could be resolved into 2 components. Vector analysis indicated a high-affinity site with  $K_D$  of  $6.1 \pm 2.5$  nM and  $B_{\text{max}}$  of  $11.8 \pm 3.5$  fmol/mg protein and a low-affinity site with  $K_D$  of  $114.2 \pm 13.2$  nM and  $B_{\text{max}}$  of  $182.1 \pm 23.5$  fmol/mg protein. Binding was then examined after mice were administered DFP by inhalation. Brain homogenate from treated mice that were sacrificed 20 min after exposure did not produce significant alterations from control in either the high- or low-affinity nicotine binding parameters. However, brain homogenate from treated mice that were sacrificed 24 hrs after exposure resulted in statistically significant differences in the low-affinity  $K_D$  and  $B_{\text{max}}$  from control values. No significant alterations were found in the high-affinity binding parameters. In light of the small changes seen only in the low-affinity binding parameters 24 hrs after DFP treatment, we conclude that DFP has only minimal effects on the mouse brain nicotinic cholinergic receptor. (Supported by USAMRDC Contract #DAMD 17-82-C-2212).

HANSCH ANALYSIS OF THE 5-HT<sub>2</sub> BINDING AFFINITIES OF A SERIES OF 2,5-DIMETHOXYPHENYLISOPROPYLAMINES. M. Seggel\*<sup>1</sup>, M. Youssif\*<sup>1</sup>, M. Titeler\*<sup>2</sup>, R.A. Lyon\*<sup>2</sup> and R.A. Glennon\*<sup>1</sup>, <sup>1</sup> Dept of Med Chem, MCV/VCU, Richmond, VA 23298 and <sup>2</sup> Dept of Pharmacology, Albany Med Col, Albany, NY. Certain substituted phenylisopropylamines bind to central serotonin (5-HT) binding (receptor) sites. Of these, the 2,5-dimethoxy analogs (2,5-DMA's) are selective for [<sup>3</sup>H]ketanserin-labeled 5-HT<sub>2</sub> sites; the nature of the 4-position substituent has a profound effect on binding affinity/selectivity. Hansch analysis of a series (K<sub>i</sub> ranging from 10 to 50,000nM) of 18 2,5-DMA's has been performed to determine what features (i.e. lipophilic, electronic, steric) of the 4-substituents are important for binding. Lipophilicity appears to be the single most important feature:  $-\log K_i = 0.54\pi + 6.02$ ,  $r = .76$ ,  $s = .74$ ,  $n = 18$ , suggesting that there is a lipophilic site on the receptor with which the 4-substituent interacts. Inclusion of electronic or steric terms does not appear to have a significant or consistent effect. For those compounds in the series with known agonist activity, Verloop's steric parameter, B<sub>1</sub>, appears to be important:  $-\log K_i = 2.13B_1 + 3.26$ ,  $r = .86$ ,  $s = .42$ ,  $n = 11$ . However, electronic effects may now also be important:  $-\log K_i = 2.65B_1 - 1.30 \text{ Sigma(meta)} + 2.66$ ,  $r = .94$ ,  $s = .30$ ,  $n = 11$ . The fact that no single model is entirely satisfactory reflects the complexity of the drug-receptor interaction.

USE OF A SUBCUTANEOUS IMPLANT TO MEASURE WOUND HEALING IN ANIMALS. T. Smith,\* J.C. Kim,\* S. Maygarden,\* I.K. Cohen\* and R.F. Diegelmann. Div. of Plast. and Reconst. Surg., MCV/VCU, Richmond, VA 23298. A wound chamber consisting of a small reservoir and a perforated segment of silicone tubing was used to collect and analyze wound cells and connective tissue formation in rats. The sterile chambers were slipped into subcutaneous pockets made on the backs of Sprague Dawley rats (240 gm). The cells obtained in the aspirates taken each day up to day 14 were counted using a cytometer and aliquots were prepared for differential staining. There was a characteristic influx of neutrophils, followed by macrophages, lymphocytes, highly activated macrophages and then fibroblasts. On day 14, the connective tissue within the lumen of the silicone tube was removed and analyzed for collagen synthesis by measuring <sup>3</sup>H-proline incorporation into collagenase-sensitive protein. If rats were pre-treated with Solumedrol (20 mg/kg) during the course of the study, there were marked changes in the inflammatory cell characteristics and biochemical analysis of the radioactive collagen showed significant depression of relative collagen synthesis; 6.8% compared to 17.1% in the control group (n=6). This new wound healing tube has proven useful to harvest cells, fluid and tissue for cellular, humoral and biochemical analyses of wound healing. (Supported by A.D. Williams)

N-GLUCOSYLATION OF AMOBARBITAL IN HUMANS. Phyllis J. Soine, Dept. of Chem., Randolph-Macon Col., Ashland, Va. 23005, & Bruce W. Overton and William H. Soine, Dept. of Medicinal Chem., Va. Commonwealth Univ., Richmond, Va. 23298. Since coupling glucose to the nitrogen of amobarbital leads to formation of two diastereomers, it was of interest to determine if enantioselectivity was observed in formation of this conjugate. A reversed phase HPLC system was developed that was capable of differentiating and quantitating amobarbital and the N-glucose conjugates of amobarbital. Following oral administration of 100 mg sodium amobarbital to humans (n=4), total urine was collected for 24 hours and morning urine was collected for the next 5 days. It was observed that one diastereomer (AMO B) accounted for 20-45% of the dose and the other diastereomer (AMO A) accounted for 0.3-3% of the dose in three individuals but was not observed in one individual. Unchanged amobarbital accounted for 3-6% of the dose. AMO B could still be detected in the urine 110 hours after dosing. AMO A and AMO B were isolated from urine and compared to synthetic standard by ir, proton nmr, ms and optical rotation. (Supported by the Epilepsy Foundation of America and the A.D. Williams Student Summer Research Fellowship)

AN ETHANOL-RELATED HEMOGLOBIN ADDUCT IN CHRONIC ALCOHOLICS: IDENTIFICATION AND CHARACTERIZATION. Teri L. Stockham\*, & Robert V. Blanke, Department of Pharmacology & Toxicology, Medical College of Virginia, Richmond, Virginia 23298. Frequently, chronic exposure to chemicals is difficult to document by analysis. Further, exposure to an agent at some time in the past may be troublesome to prove since the agent may be metabolized or excreted quickly. Others have shown that selected chemicals can form adducts with macromolecules such as DNA or proteins. These persist for the life of the macromolecule. It has been proposed that such an adduct is formed with hemoglobin in alcoholics. This study describes the verification of this observation in alcoholic patients. In addition, the adduct has been isolated and purified by cation exchange and affinity chromatography for the purpose of characterization. If this adduct proves to be a unique marker, it may serve to identify alcoholics or even to indicate alcohol use after conventional blood alcohol concentrations are not detectable.

PURIFICATION OF HUMAN MILK OLIGOSACCHARIDES BY AFFINITY CHROMATOGRAPHY WITH WHEAT GERM AGGGLUTININ. Maria T. Tarrago\* & David F. Smith, Dept. of Biochemistry & Nutrition, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Wheat Germ Agglutinin is a lectin which is considered to have specificity for N-Acetyl Neuraminic Acid (NeuAc). Human milk sialyl-oligosaccharides contain NeuAc attached to other carbohydrates in a variety of linkages. Based on this, <sup>3</sup>H labeled human milk oligosaccharides were assayed for their ability to bind WGA covalently linked to agarose. Among all sialyl-oligosaccharides, a single high molecular weight oligosaccharide was able to bind WGA. After treatment of the affinity-purified oligosaccharide with neuraminidase to remove, NeuAc the resulting neutral sugar demonstrated a higher affinity for the WGA-agarose column. These results indicate that NeuAc is not important in the binding of human milk sialyl sugars to WGA. Structural analysis of the affinity-purified oligosaccharide will provide additional information on the carbohydrate specificity of WGA.

CORRELATION OF THE NEUROCHEMICAL AND BEHAVIORAL EFFECTS OF ORGANOPHOSPHATES IN RODENTS. Hem L. Tripathi\*, A.R. Szakal\*, D.M. Little\* and W.L. Dewey, Department of Pharmacology, Medical College of Virginia, Richmond, VA 23298. Studies were carried out to investigate a possible correlation between acetylcholinesterase (AChE) inhibition and behavioral effects of soman, sarin and tabun in mice. The acute intravenous LD50s (C.L.) of soman, sarin and tabun were 42(35-50), 109(101-118) and approximately 250 µg/kg, respectively. All three compounds caused a decrease in spontaneous activity and body temperature in a dose-related manner. Soman 25, sarin 80 and tabun 200 µg/kg produced similar behavioral effects but inhibited brain AChE to a different extent; 44, 84 and 74 percent, respectively. AChE activity was inhibited in a dose-dependent manner in whole mouse brain, as well as in six brain regions. Brain areas were almost equally inhibited by each organophosphate. Spontaneous activity and body temperature returned to control value within 24 hr although brain AChE was inhibited longer than two weeks by each organophosphate. AChE inhibition and pharmacological changes suggest that the brain compensates for the enzyme inhibition or that neurochemical changes other than AChE inhibition are involved in producing pharmacological effects. (Supported by U.S.A.M.R.D.C. Contract #DAMD17-82-C-2174).

STIMULATION OF SECRETION OF CELLULAR STORAGE POOL OF FIBRINOGEN BY A SEPTIC TISSUE DERIVED FACTOR. J.A. Walck, H.J. Evans, G.D. Qureshi. Departments of Medicine and Biochemistry, Medical College of Virginia, Richmond, VA.

Our previous studies have suggested that the cellular storage compartment of fibrinogen may be of significant size, the release of which may be independent of the new synthesis. Isolated functions of secretion and new synthesis of fibrinogen in cells was studied in rat hepatocyte cultures in which total secreted fibrinogen was measured by RIA, the newly synthesized fibrinogen by immunoprecipitation of  $^3\text{H}$ -Leucine labeled fibrinogen and albumin by quantitative immuno-electrophoresis. Addition of a septic abscess homogenate (RSATH) to monolayer cultures caused a dose dependent release of stored fibrinogen from hepatocytes without affecting the rate of new synthesis. Secretion of albumin remained unchanged. Purification of RSATH on HPLC resulted in isolation of a peptide (MW 68K) which specifically stimulated the release of fibrinogen. Rat neutrophils, monocytes/macrophages or endotoxin (*E. coli*, 20 and 50 ug/3ml) had no effect on the release of fibrinogen by hepatocytes. We conclude that: (1) the storage pool of fibrinogen in hepatocytes is significantly large; (2) secretion of this pool of fibrinogen may be stimulated by a 68K M.W. peptide which may play a role in causing acute hyperfibrinogenemia in clinical conditions of sepsis.

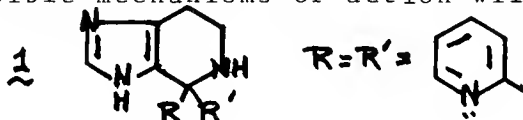
THE ROLE OF CALCITONIN AND CALCITONIN GENE-RELATED PEPTIDE (CGRP) IN THE MODULATION OF OPIATE ANALGESIA. Sandra P. Welch\* and W.L. Dewey, Dept. of Pharmacology and Toxicology, Medical College of Virginia, Richmond, VA. 23298

Calcitonin (CT) and CGRP were evaluated in various *in vivo* and *in vitro* bioassays to evaluate their intrinsic analgesic activity in mice, their activity in the electrically stimulated guinea pig ileum assay (GPI), and the modulatory effects of both on morphine's effects *in vivo* and in the GPI. The effects observed were then correlated to the modulation of calcium by CT and CGRP in the central nervous system (CNS) as measured by calcium uptake to synaptosomes. CT and CGRP produced biphasic time dependent effects *in vivo* and *in vitro*. Within 5 minutes post administration intraventricular CT and CGRP antagonize morphine in the tail-flick test. CT also antagonizes morphine in the GPI. At this time, both peptides decrease calcium uptake to synaptosomes. However, by 1 hr (CGRP) or 2 hr (CT) calcium uptake is reduced. At this time point, both peptides are maximally analgesic, produce inhibition of the GPI, and potentiate or are additive with morphine in the GPI and in the tail-flick test. Naloxone will reverse the inhibition of GPI, decreased calcium uptake and the analgesic effects of both peptides. The effects of both peptides appear to correlate to modulation of calcium. (Supported by USPHS Grants DA-01647 and T32 DA-07027).

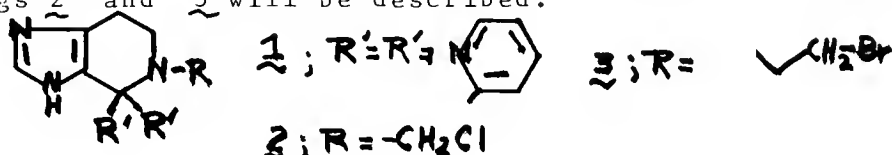
THE EFFECTS OF DIVALENT METAL AND POLYAMINE CATION COMPLEXATION ON THE CONFORMATION OF DIADENOSINE TETRAPHOSPHATE. Richard B. Westkaemper\* and David E. Pereira\*, Dept. of Medicinal Chemistry, School of Pharmacy, MCV-VCU, Richmond, Va 23298. Evidence is accumulating that diadenosine 5',5'''-p<sup>1</sup>,p<sup>4</sup>-tetrphosphate (Ap<sub>4</sub>A) is a signal nucleotide that has a role in the initiation of DNA replication. The conformation of this unique dinucleotide and changes in conformation induced by complexation with biologically important cations may be of importance in determining the mode of interaction of Ap<sub>4</sub>A with nucleic acids and proteins. Previously reported circular dichroism (CD) studies have shown that Ap<sub>4</sub>A adopts a unique folded conformation in solution in which the purine bases in the anti configuration, intramolecularly stacked with alpha faces opposed. CD spectra of 1:1 complexes of Ap<sub>4</sub>A with putrescine, spermidine, spermine, and magnesium cations show symmetrical decreases in ellipticities that can be attributed either to a disruption of base stacking interactions or changes in the orientation of the interacting chromophores in a stacked conformer. Proton magnetic resonance spectra of Ap<sub>4</sub>A show that the signals of the two aromatic protons H-2 and H-8 are shifted upfield relative to AMP, ADP, and ATP providing further evidence for a significant degree of base stacking interaction in a folded conformation. Disruption of the base stacked conformation induces a large downfield shift in the aromatic resonances. Small upfield shifts are observed for H-2 and H-8 on complexation of Ap<sub>4</sub>A with putrescine, spermidine, spermine, and magnesium. These results are consistent with an enhancement of base stacking interactions rather than disruption of the folded structure. (Aided by grant IN-1055 from the American Cancer Society)

IMMUNOLOGICAL MECHANISMS IN *NAEGLERIA FOWLERI* INFECTION L.Y. Whiteman and F. Marciano-Cabral, VA Commonwealth Univ./M.C.V., Richmond, VA 23298. *N. fowleri* is the etiologic agent of primary amoebic meningoencephalitis, a fatal disease of the central nervous system. The complement system is an important host defense against *Naegleria* infection. Four species of *Naegleria* were compared by an in vitro cytotoxicity assay for their susceptibility to complement mediated lysis. *Naegleria* amoebae were labeled with 25  $\mu$ Ci of  $^3$ H-uridine. Release of label from amoebae was used as an index of lysis. Susceptibility to complement mediated lysis correlated with pathogenicity. The highly pathogenic mouse passaged strain of *N. fowleri* (LEEmp) was less susceptible to lysis by human serum complement or guinea pig complement. The moderately pathogenic *N. australiensis* was moderately susceptible to complement mediated lysis, and the nonpathogenic species, *N. gruberi* and *N. lovaniensis*, were highly susceptible to lysis. Heat inactivation (56 C, 30 min) removed the amoebicidal activity of serum. The presence of specific antibody significantly enhanced the amoebicidal activity of complement. The results indicate that the more pathogenic species of *Naegleria* are more resistant to the lytic effects of complement. (Supported in part by the Thomas F. Jeffress and Kate Miller Jeffress Memorial Trust, Richmond, VA).

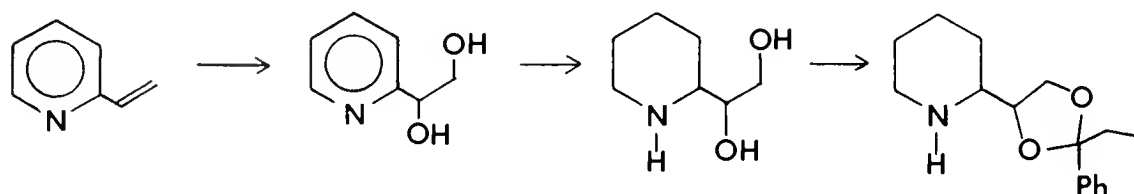
CARDIOVASCULAR ACTIVITY OF 7,7'-DIPYRIDYL-4,5,6,7-TETRAHYDROIMIDAZO(4,5-C)PYRIDINE. R.L. WILLIAMS, Joseph Delos Angeles<sup>1</sup> and Patricia Williams<sup>2</sup>, <sup>1</sup> Dept. of Chemical Sciences, Old Dominion University Norfolk, Va. 23508 and <sup>2</sup> Dept. of Pharmacology, Eastern Virginia Medical School, Norfolk, Va. 23501. The parent compound in this study 7,7'-dipyridyl-4,5,6,7-tetrahydroimidazo-(4,5-C)pyridine 1 has been shown to exhibit neuromuscular blocking activity as well as explosive motor activity. We now wish to describe the cardiovascular activity associated with this unique compound. Compound 1 produces a dramatic drop in blood pressure and a corresponding increase in heart rate at both 10 and 15 mg/Kg in rats(ip). Several structural analogs have been examined which provide some clues as to the active pharmacophore associated with 1 and possible mechanisms of action will be discussed.



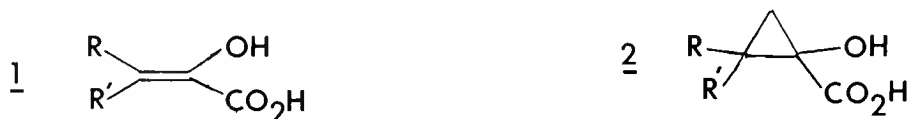
EXPLOSIVE MOTOR BEHAVIOR: STRUCTURAL ANALOGS OF THE EMB AGENT 7,7'-DIPYRIDYL-4,4,6,7-TETRAHYDROIMIDAZO-(4,5-C)PYRIDINE. R.L. Williams, Robert Gabler and Pat Roberts, Dept. of Chemical Sci., Old Dominion University, Norfolk, Va. 23508. 7,7'-Dipyridyl-4,5,6,7-tetrahydroimidazo-(4,5-C)pyridine 1 has been found to produce explosive motor behavior (EMB) by ip and ivt administration to test animals. In an effort to more fully understand the mechanism of action associated with this drug, we have attempted to modify the structure in ways which would alter the potential bipyridyl pharmacophore and eliminate the EMB activity. This work has resulted in several new analogs in which alkyl halo side chains have been introduced into the parent system. The activity of these two analogs 2 and 3 will be described.



SYNTHESIS OF THE DIASTEREOMERS OF 2-ETHYL-2-PHENYL-4-(2-PIPERIDYL)-1,3-DIOXOLANE (ETOXADROL) AS PROBES OF THE PHENCYCLIDINE RECEPTOR. Paul C. Zenk, Everette L. May,\* and Robert L. Balster,\* Department of Pharmacology and Toxicology, Medical College of Virginia, Virginia Commonwealth University, Richmond, Virginia 23298. In rats trained to discriminate phencyclidine (PCP) from saline, etoxadrol generalized to PCP in a dose dependent manner. To determine the biological activity of the eight possible enantiomers of etoxadrol, their synthesis was undertaken. The synthetic strategy used (see scheme) and preliminary biological data will be discussed. (Supported by NIDA grants DA-07027 and DA-00490)



SYNTHESIS AND EVALUATION OF SUBSTITUTED HYDROXYCYCLOPROPANE CARBOXYLIC ACIDS AS POTENTIAL TRANSITION STATE INHIBITORS OF DIOL DEHYDRATASE. Paul C. Zenk<sup>1</sup>, and Richard B. Westkaemper\*<sup>2</sup>, <sup>1</sup>Department of Pharmacology and Toxicology, <sup>2</sup>Department of Medicinal Chemistry, School of Pharmacy, MCV-VCU, Richmond, Va, 23298. Diol dehydratase (EC 4.2.1.9) catalyzes the magnesium ion dependent dehydration of 2,3-dihydroxy-3-methylbutanoic acid and 2,3-dihydroxy-3-methylpentanoic acid to the respective alpha-keto acid precursors of the branched chain amino acids valine and isoleucine. The enzymatic reaction proceeds through a discrete enol (**1**) intermediate which is stereospecifically protonated at the active site prior to release of product from the enzyme. Substituted hydroxycyclopropane carboxylic acids (**2**; R,R'=H; R,R'=CH<sub>3</sub>; R=CH<sub>3</sub>, R'=CH<sub>2</sub>CH<sub>3</sub>) are stable analogs of the transition state leading to the reactive enol intermediate. The substituted cyclopropanes were found to be moderately effective competitive inhibitors of dehydratase from bakers yeast and *E. coli*.



## Microbiology

ISOLATION AND CHARACTERIZATION OF PSEUDOMONAS AERUGINOSA MUTANTS DEFICIENT IN GLUCOSE-6-PHOSPHATE DEHYDROGENASE AND PYRUVATE CARBOXYLASE. Frank R. Bowman & J. E. Gates, Dept. of Biol., Va. Commonwealth Univ., Richmond, VA. 23284, and P. V. Phibbs, Dept. of Microbiol./Immunol., East Carolina Univ. Sch. of Med., Greenville, NC, 27834. Four EMS induced mutants were isolated from the glucose-6-phosphate dehydrogenase (ZWF) deficient strain of *P. aeruginosa* (PFB98) which were unable to utilize a wide array of carbohydrates and therefore presumed to be deficient in pyruvate carboxylase (PYC) activity. Preliminary enzyme assays confirmed the absence of both ZWF and PYC. Spontaneous revertants have been isolated which regained the ability to catabolize glucose, gluconate and pyruvate but not mannitol suggesting that the PYC deficiency was due to a point mutation. As both ZWF and PYC may be important regulatory enzymes, such double mutants should prove useful in the study of the regulation of carbohydrate catabolism in this important microorganism.

DEFECTIVE DEVELOPMENT OF THE ANTIGEN RETAINING RETICULUM (ARR) CORRESPONDS WITH A DEFECTIVE SECONDARY ANTIBODY RESPONSE IN AGED MICE. Greg F. Burton<sup>1</sup>\*, Andras Szakal<sup>2</sup>, and John G. Tew<sup>1</sup>, Dept. of Microbiol. and Immunology<sup>1</sup> & Dept. of Anatomy<sup>2</sup>, Va. Commonwealth Univ., Richmond, VA, 23298. Recent data from our laboratory suggest that follicular dendritic cells (FDC) play an important role in the initiation of the secondary antibody response. Additional findings indicate that the ARR of lymph nodes, which is composed of FDCs, does not develop properly in aged mice. We therefore predicted that the secondary antibody response should be impaired in aged mice. The purpose of this study was to determine if a depression in the secondary antibody response in aged mice could be confirmed and if it correlated with a defective ARR. Development of the ARR was assessed using the histochemically identifiable antigen horseradish peroxidase (HRP). The secondary antibody response was determined by radioimmunoassay of serum anti-HRP. Twenty-seven month old mice were injected with HRP and boosted on day 14. Two weeks later the animals were bled and their draining lymph nodes collected. The FDC comprised ARR either failed to develop or was poorly organized and significant quantities of HRP were retained in the subcapsular sinus of the nodes. Anti-HRP levels were depressed in both the primary (92 vs 388 mcg ab/ml) and the secondary antibody response (235 vs 2059 mcg ab/ml) in aged vs young mice. These findings are consistent with the concept that FDCs play an important role in the induction of the secondary antibody response and suggest that part of the immune deficit in aged mice may be attributable to a deficit in FDC function.

#### CHARACTERIZATION OF CADMIUM SUSCEPTIBILITY IN MYCOBACTERIUM SCROFULACEUM.

Frank X. Erardi and Joseph O. Falkinham III, Dept. of Biology, Va. Polytechnic Institute & State University, Blacksburg, Va. 24061. Two strains of Mycobacterium scrofulaceum, one a cadmium-resistant strain (strain W262) and the other a cadmium-sensitive strain (strain LR199), were investigated in an attempt to identify the possible mechanism(s) of cadmium-resistance in strain W262. Growth of strain LR199 in Middlebrook M7H9 broth medium containing 5  $\mu$ M CdCl<sub>2</sub> was inhibited by 50%, whereas a 200 fold higher concentration (i.e. 1 mM) was required to inhibit the growth of strain W262 by 50%. However, there was little or no difference in the susceptibilities of the two strains to the divalent cations Ca, Co, Cr, Cu, Fe, Hg, Mn, Ni and Zn. Transport of Cd-109 by both strains was apparently via an active transport system, being inhibited by CCCP and DNP, and at 0°C. The resistance to cadmium of strain W262 was not due to a decreased accumulation of cadmium, because both strains accumulated approximately equal levels. Proteins, synthesized by strain W262 when grown in the presence of cadmium, may play an important role in the cadmium-resistance of strain W262.

#### ANTIBIOTIC PRODUCTION BY BACTERIA ISOLATED FROM THE LOWER CHESAPEAKE BAY.

Linda Gilmer Mangiaracina, F. L. Singleton, and A. S. Gordon. Old Dominion Univ., Norfolk, VA 23508 and Mar. Biotech. Ctr. Univ. of Md., College Park, MD 20742. Novel antibiotics are constantly in demand due to the occurrence of bacteria resistant to antibiotics currently in use. The marine environment is largely unexplored for antibiotic producing microorganisms. The Chesapeake Bay, due to its variability in chemical and physical parameters, harbors a diversity of microenvironments and microbes, and thus, may yield new antibiotic producing strains. In the present study, 1500 bacteria were isolated from various sources in the lower Chesapeake Bay. Epiphytic bacteria were isolated from brown algae and green algae. Epizoic bacteria were isolated from the skin and intestine of bluefish and flounder. Free floating bacteria were isolated from the top and bottom of the water column. Bacterial isolates were screened for production of antibiotics effective against selected human pathogens. Thus far, two percent of the bacteria tested have demonstrated antibiotic activity. Preliminary screening is ongoing.

ALGINATE EFFECTS ON THE ATTACHMENT OF VIBRIO ALGINOLYTICUS AND VIBRIO PELAGICA TO STAINLESS STEEL IN SEAWATER. A. S. Gordon, Dept. of Biol. Sci., Old Dominion Univ., Norfolk, VA, 23508. Bacterial attachment to metal surfaces in seawater is an important first stage in the succession of surface associated organisms that leads to gross fouling of the surface. Bacterial attachment (microfouling) is preceded by adsorption of macromolecular organic compounds onto the metal surface. These organic compounds include proteins, proteoglycans and polysaccharides. It has been suggested that heterotrophic bacteria are attracted to surfaces which are coated with this film of organic compounds because the organic material represents a food source for the bacteria. In the present study the influence of adsorbed alginate on the attachment of epibacteria which can and cannot use alginate as a sole carbon and energy source is being examined. The results indicate that, when the bacteria were in stationary growth phase, alginate inhibited attachment presumably by altering the surface charge of the metal. When the bacteria were in exponential growth phase, attachment of the bacterium which utilized alginate was not inhibited and, under some conditions, was greatly increased.

SERUM ANTIBODIES REACTIVE WITH HAEMOPHILUS ACTINOMYCETEMCOMITANS AND BACTEROIDES GINGIVALIS IN JUVENILE PERIODONTITIS FAMILIES. C.M. Gooss\*, R.R. Ranney\*, A.G. Sarbin\* and J.G. Tew. VCU Clin. Res. Cntr. Perio. Dis. Richmond, VA 23298. Young adults with juvenile periodontitis (JP) frequently exhibit high titers of antibody specific for Haemophilus actinomycetemcomitans (Ha) and/or Bacteroides gingivalis (Bg), whereas high titers are rare in young, healthy, unrelated controls. This study examined 24 JP families plus a large number of unrelated individuals. All subjects were classified by clinical examination. IgG-specific serum antibody titers reactive with Ha (strain Y4) and Bg were determined using a sensitive radioimmunoassay. High titers of both anti-Ha and anti-Bg were detected throughout most families regardless of periodontal disease status (e.g. high titers were commonly exhibited by healthy family members, whereas unrelated healthy controls rarely exhibited high titers). In addition a striking similarity of titers was noted between members of families who had lived in the same household regardless of periodontal disease status. In contrast, family members raised separately did not exhibit such similarity of titers. This suggests that both Haemophilus actinomycetemcomitans and Bacteroides gingivalis are communicable within the context of a family environment but often not in association with severe periodontal destruction. Supported by NIH Grant DE05139.

COXSACKIEVIRUS B4 INFECTION IN THE DIABETIC MUTANT BB RATS. Te-Chung Lee\* and Roger M. Loria\*, Dept. of Microbiol. and Immunol. Va. Commonwealth Univ. Richmond, VA 23298. Diabetic mutant mice C57BL/KsJ db/db were shown to have an impaired humoral immunity to coxsackievirus B4 (CB4). In this diabetic mutant, CB4 infection did not cause a marked reduction in spleen cell counts as was seen in the nondiabetic controls. Diabetic prone and resistant BB rats were infected with CB4, leading to an extreme glucose intolerance in diabetic prone rats. In both groups, a 30% reduction in spleen weights was observed 14 days postinfection. Preinfection spleen cell counts in diabetic prone rats were markedly lower than in the resistant rats. However, they were comparable at 20 days postinfection due to a 70% reduction in spleen cell counts in the diabetic resistant rats. The BB rats did not develop serum neutralization antibodies following CB4 infection. In summary, a similar reduction in spleen cell counts in both diabetic resistant and prone rats following CB4 infection was observed. The selective effects of CB4 on the spleen weight and cell counts in the BB rats are in contrast with its effects in diabetic mutant mice.



POLYCLONAL B CELL ACTIVATION (PBA) IN PERIODONTITIS: LOCAL SPECIFIC ANTIBODY SYNTHESIS FOR THE NON-ORAL ANTIGEN TETANUS TOXOID. S. M. Mallison<sup>1</sup>, R. R. Ranney<sup>2</sup>, and J.G. Tew<sup>1,2</sup>. Dept. of Microbiology and Immunology<sup>1</sup>, and the Research Center for Periodontal Disease<sup>2</sup>, Virginia Commonwealth University, Richmond, VA. Gingival crevicular fluid (GCF) is exuded from periodontal lesions. GCF from many human subjects has shown elevated specific-antibody titers (titers 2 to 8 fold excess of serum) to several periodontitis-associated bacteria indicating local specific-antibody synthesis. Periodontitis-associated bacteria are potent polyclonal B cell activators *in vitro* and we reasoned that PBA may be occurring in periodontal lesions. Subjects were immunized subcutaneously with 10 µg tetanus toxoid (TT) in alum. Serum and GCF (from 8 different sites) were collected once before and every 2 to 3 days after immunization out to 21 days. On days 9-14 two of eight gingival sites showed anti-TT antibody titers well in excess of serum as determined by radioimmunoassay. This is strong evidence that anti-TT antibody was produced locally for this non-oral antigen. Because the booster dose was low it is unlikely that antigen stimulated B cells in the gingiva to become antibody producing cells. These results support the contention that PBA does occur in periodontitis. Supported by NIH grants DE05139 and T32-CA09210.

SEQUENCE DATA FROM DELETIONS OF CLONED LAPINE PARVOVIRUS DNA. J.B. Metcalf, B.C. Shull, M. Lederman, E.R. Stout, and R.C. Bates, Dept. Biology, Virginia Tech, Blacksburg, VA 24061. Rabbit parvovirus (LPV) has a number of similarities to bovine parvovirus (BPV). LPV has three major capsid proteins which are slightly larger than the three capsid proteins of BPV. In comparison, the other rodent parvovirus have only two major capsid proteins. LPV also has three nonstructural proteins, one of which is approximately the size of NP-1, a nonstructural protein of BPV. The LPV genome appeared to be at least the size of the 5.5 kb BPV genome or slightly larger. Immunological analysis by immunoprecipitation, Western blotting, and fluorescent antibody staining has shown no cross reactivity between BPV and LPV. DNA/DNA hybridization between restriction fragments of BPV and nick translated, *in vitro* replicated LPV suggested that there was no homology between the genomes. To confirm this observation, viral DNA of LPV was isolated, replicated *in vitro*, and restriction fragments cloned into pUC8 and M13mp18 and 19. Preliminary sequence data from a set of nested overlapping deletions of a 5.3 kb Eco RI restriction fragment constructed in M13mp18 and 19 show no homology between LPV and BPV, but data covering more extended regions of the genome will be required to conclude absolute lack of relation between these viruses.

INCREASED LEUKOCYTE DIVERSITY AND RESPONSIVENESS TO B CELL AND T CELL MITOGENS IN CELL SUSPENSIONS PREPARED BY ENZYMATICALLY DISSOCIATING MURINE LYMPH NODES. Alan P. Monfalcone\*, Andras K. Szakal, John G. Tew, Dept. of Microbiology and Immunology, MCV, Richmond, Va. 23298. Isolation of fragile cell types such as follicular dendritic cells (FDC's) from murine lymph nodes requires an enzyme dissociation with collagenase and the protease dispase. We undertook this study to examine the other cell types enriched by enzyme dissociation compared to mechanical disruption (teasing with forceps and wire screen). Corresponding lymph nodes from either side of the animal were removed and subjected to one of the two cell isolation procedures. We examined cell viability, cell number, and the proliferative response to the mitogens LPS, PHA, and Con A. We found that we recovered more cells with more viable cells that had increased responsiveness to the B cell mitogen LPS and the T cell mitogens PHA and Con A. We conclude that the method of cell isolation is important and that enzyme dissociated cell populations may more accurately represent *in vivo* conditions.

SMALL RNA SPECIES IMPLICATED IN NOVEL mRNA MATURATION PROCESSES IN TRYPANOSOMES. V.A. Schroeder, C. McCarthy and G.A. Buck. Dept. of Microbiology, Va. Commonwealth University, Richmond, Va. 23298. Most or all trypanosomes mRNAs share an identical 35 base leader element (LE). A LE-bearing RNA that varies in size (80-150b) among trypanosome species has been reported to be the primary transcript of the LE. We examined the LE-bearing sequences in RNA from *T. equiperdum* by Northern hybridization using synthetic oligonucleotide probes. A probe complimentary to the LE hybridized to a ~150b putative primary LE transcript in RNA isolated from purified trypanosomes. However, RNA from trypanosomes lysed directly in host blood lacked the ~150b transcript, suggesting that a larger primary transcript may be processed to yield the ~150b species. A probe complimentary to non-LE regions of the putative primary transcript hybridized to a ~200b RNA species that did not hybridize to the LE probe but no large potential primary transcripts were observed. The implications of these observations will be discussed.

DIRECT CLONING OF THE BOVINE PARVOVIRUS GENOME. B.C. Shull, R.C. Bates, and E.R. Stout, Dept. Biology, Virginia Tech, Blacksburg, VA 24061. Bovine Parvovirus (BPV), a member of the autonomous parvoviruses, has a single-stranded DNA genome of 5491 bases. BPV separately encapsidates both plus and minus strands. Reannealed duplex virion DNA may be recovered from neutral high salt sucrose gradients. We have used reannealed virion DNA to obtain full length clones of BPV by blunt end cloning into plasmid pUC8. These clones have proven to be stable upon propagation in *E. coli* JM107, despite the presence of terminal palindromes. Calcium phosphate transfection was used to introduce the cloned DNA into host bovine fetal lung cells. The transfected cells produced BPV antigens and gave rise to infectious progeny virions. Staining of transfected cell monolayers demonstrated an infectivity of about 100 plaque-forming units/ $\mu$ g of DNA. Using the cloned DNA we have constructed a deletion mutant in which the Kpn I fragment from map 43 to 91 of BPV has been specifically removed. We are currently mapping the genetic functions of BPV by transfection of such deleted cloned genomes.

SERUM ANTIBODY TITERS TO PREDOMINANT ORGANISMS IN JUVENILE PERIODONTITIS. S. Thomas\*, D. Marshall\*, R.R. Ranney\*, K.G. Palcanis\*, & J.G. Tew. VCU Clin. Res. Ctr. for Perio. Disease Richmond, Va. 23298. The objective of this study was to establish whether young adults with localized juvenile periodontitis (JP) have an increased incidence or elevated titer of antibody against predominant organisms in their subgingival flora. For comparison, sera from similarly aged healthy (HP) subjects and subjects with generalized severe periodontitis (SP) were also tested (N=about 50 in each group). A sensitive radioimmunoassay was used. A series of oral bacteria were tested. The incidence of positive response was significantly higher ( $p<.01$ ) in JP than HP for *Haemophilus actinomycetemcomitans* (HA) (three serotypes a,b,c) and *Bacteriodes gingivalis*. The response frequency to HA (serotype b) by JPs was also higher ( $p<.01$ ) than by SPs. In conclusion, antibody specific for a number of organisms were found to distinguish JP status from HP. Antibody specific for HA (serotype b) also correlated better with JP than SP. However, JP and SP responses to most organisms were similar. This is consistent with the similarity of the associated floras. (Supported by NIH Grant DE05139)

## Psychology

MAGNITUDE ESTIMATIONS OF SWEETNESS IN COMPOUNDS OF SWEET AND BITTER FLAVOR CONCENTRATIONS. Ruth J. Arnegard, Christine L. Slank, and Katherine S. Marshall, Dept. of Psyc., VPI & SU, Blacksburg, Va. 24061. Differences in eating behavior between dieters and nondieters may reflect the dieters' greater responsiveness to taste stimuli, especially sweet tastes, relative to that for nondieters (Nisbett, 1972). Since sweet tastes are typically viewed as highly palatable and palatability has been reported to be hunger-dependent (LeMagnen, 1978) we investigated the relationship between hours of food deprivation and judgments of sweetness intensity and preference. Twenty-six women were asked to use a magnitude estimation procedure in judging the sweetness of 2%, 4%, 8%, 16% and 32% concentrations of sucrose which were orthogonally combined with 0, .75%, 1.0%, 1.5% and 2.0% urea (bitter) under low (0-1.5 hours) and moderate (2-6 hours) levels of food deprivation. Subjects also indicated how much they liked the taste of the solutions. Results showed that judgments of sweetness intensity increased with sucrose concentration but were generally lowered as concentrations of bitter increased for each level of sucrose. Preference behavior was nondifferential across sucrose levels but was inversely related to concentrations of bitter. Deprivation level and hunger ratings did not exert a reliable influence on judgmental responding.

EFFECTS OF ETHANOL-INDUCED TOXICOSIS ON AVERSION CONDITIONING TO WINE AND BEER. Bradley Bennett.\* Dept. of Psychology, Va. Polytechnic Inst., Blacksburg, Va. 24061. Rats (Rattus norvegicus) received intraperitoneal injections of 15%, 30% or 45% (v/v) ethyl alcohol (ethanol) following ingestion of beer of high or low congener contents or of wine of high congener contents. The specific alcoholic beverages ingested were Budweiser (high congener) or Michelob (low congener) beer or Gallo burgundy (high congener) wine. Aversion effects produced by injection of alcohol were measured by subsequent intake of each beverage. Results showed that, for each beverage, injection of 45% ethanol produced greater aversion effects than did injection of 30% or 15% ethanol. Effects of the latter injections did not differ from each other. The magnitude of aversion effects was greater, the higher the congener level of beer. Aversion effects to wine were intermediate to the effects for beer.

AVERSION CONDITIONING TO VISUAL AND GUSTATORY STIMULI IN CHICKENS (GALLUS DOMESTICUS). Karen A. Boling,\* Antoinette B. Dyer,\* and David L. Tarnoff,\* Dept. of Psychology, Va. Polytechnic Inst., Blacksburg, Va. 24061. To study the relative salience (conditionability) of visual and gustatory cues in aversion conditioning in chickens ( $n = 21$ ), 30-day old chickens drank 3% (v/v) vinegar from a clear or a red-colored tube or they drank water from a red-colored tube. After drinking, chickens in the conditioning group received an intraperitoneal injection of .4M LiCl at 2.0% body weight. Control chickens received an injection (i. p.) of isotonic saline. On the next day all chickens drank water followed by an injection of isotonic saline for conditioning groups or an injection of LiCl for controls (to control for the ingestion-toxin contingency). After three days for recuperation from the effects of the toxin each chicken was tested for aversion with the original CS, either vinegar alone, vinegar in a red tube or water in a red tube. On trial 1 of testing aversion effects were similar for the compound CS of taste and color and for color or taste alone. However, on trials 2 and 3 aversion effects to color dissipated to the level of control groups. Aversion to the compound CS or to taste alone remained essentially unchanged from the level of trial 1.

ALZHEIMER'S DISEASE: EFFECTS ON MEMORY OF THE ISOLATION OF THE HIPPOCAMPUS. John-Paul Bouffard, Leonard E. Jarrard, Dept. of Psychol., Washington and Lee University, Lexington, VA 24450. The effects of ibotenate lesions to hippocampus proper and to subiculum/entorhinal cortex were studied using a radial maze acquisition task. Subjects were also tested for differences in radial maze performance between massed and distributed practice for the radial maze task. Hippocampal animals performed significantly worse than controls on all aspects of the task, but subiculum/entorhinal animals did not differ significantly from controls on any dependent measure. The primary impairment for hippocampal animals was on working memory. Distributed practice effects were minimal, but facilitated hippocampals' performance on working memory, and all groups' performance on reference memory. The data are discussed in terms of relevant theories of hippocampal function, and current data in human literature implicating the possible role of the hippocampal formation in Alzheimer's Disease. The data seem to fit best with Olton's working memory theory, and contradict theories proposed by Rawlins and Gray.

CHANGES IN FAN BEHAVIOR ACROSS A BASKETBALL SEASON. Steven W. Clarke\*, Dept. of Psychology, & Michael W. Metzler\*, Dept. of Education, Virginia Tech, Blacksburg, VA 24061. Universities across the country are experiencing fan behavior problems at athletic events. During the 1985-1986 men's basketball season, sections of the crowd at Virginia Tech home games were videotaped. Eight categories of game events were coded and the fans' behavior following these events were coded across five dimensions. In addition, fan apparel was observed during the 1985 football season and the 1985-1986 basketball season at Virginia Tech. Changes in fan behavior and the wearing of school-colored apparel are discussed with regards to school-sponsored special events and conference play. Behaviors which could be targeted for behavior change and the implications for the development of a fan behavior change program are discussed.

EFFECT OF VARIETY OF DIET ON THE EATING BEHAVIOR OF RATS. Stephen C. Dobratz, Dept. of Psychology, James Madison Univ., Harrisonburg, VA 22807. Based on experiments implicating the effect of variety on eating behavior, it was hypothesized that variety of diet presented successively or simultaneously would stimulate food intake and weight gain. Twenty-four subjects were divided into four groups which received either (1) unflavored mash, (2) three different flavored mashes presented one at a time, (3) eight continuous days of a single flavor followed by eight days each of the two remaining flavors, or (4) three different flavors of mash presented simultaneously. Data were obtained for body weight and amount of food consumed and were analyzed using one-between, two-within analysis of variance. Contrary to the hypothesis, the variety of diet did not significantly affect body weight or food intake. The results suggest that rats efficiently maintain their body weights and that perhaps variety does not affect food intake when lower weight rats and fewer courses are used. Results were discussed with respect to future experimentation.

THE POSITIVE AND NEGATIVE MEMORIAL EFFECTS OF GENERATING INFORMATION. David G. Elmes, J.B. Thompson\*, J.P. Bouffard, & A.J. Tartaglione\*, Dept. of Psychol., Washington and Lee Univ., Lexington, VA 24450. Mobilization of knowledge was examined in several experiments. The mobilization groups generated instances from a specified category and then studied a list containing some of the generated items as well as other members of the category that had not been generated. Control subjects received the same study list after generating instances from an irrelevant category. Prior mobilization rarely facilitated the free recall of generated study list items and inhibited the free recall of non-generated items. Recognition of generated items is facilitated, but the recognition of non-generated items is not inhibited. Apparently, mobilization and study of generated items produces interference and reality monitoring difficulties that inhibit the recall of non-generated items.

INCREASING ATTENDANCE AT WOMEN'S ATHLETIC EVENTS: AN APPLIED BEHAVIORAL ANALYSIS AND MARKETING APPROACH. Alice Farling\* & Steven W. Clarke\*, Dept. of Psychology, Virginia Tech, Blacksburg, VA 24061. Attendance at women's basketball games is only about 3% of that for men's basketball. In an attempt to increase student attendance at women's basketball games during the 1985-1986 season, two incentive-reward strategies were implemented. One program targeted freshman students in the dormitories and the other targeted all students. The dormitory program increased student attendance by an average of 20% and the university-wide program increased student attendance by an average of 26%. Results of this study are discussed in regards to the use of applied behavior analysis, by athletic departments, to increase attendance and fan support. Implications for the marketing of athletic events are also discussed.

THE STATE OF ACADEME IN A MID-SIZED VIRGINIA UNIVERSITY: A COMPARISON INVOLVING ATTITUDES REGARDING PSYCHOLOGICAL, SOCIAL, AND EDUCATIONAL ISSUES WITH A NATIONAL FACULTY SAMPLE. Chet H. Fischer, Department of Psychology, Radford University, Radford, Va. 24142. A recent survey of 500 faculty members from 310 institutions conducted by the Carnegie Foundation for the Advancement of Teaching indicated deep dissatisfaction in academe. Some of the findings included: academic standards are too low, students are too weak, the pay is inadequate, and the quality of education is declining. The Carnegie Foundation study was replicated at a mid-sized Va. Univ. The results of the **replication** suggest significantly less dissatisfaction, as compared with the national sample, concerning the financial health of the university, the quality of the students, many faculty issues, and the goals of higher education. The implications of these results were discussed.

THE EFFECT OF AGGRESSION ON LEARNED LAZINESS IN RATS. Barry Funkhouser and D.G. Elmes, Dept. of Psychol., Washington and Lee Univ., Lexington, VA 24450. This experiment examined the effects of the opportunity to aggress in animals following exposure to response-independent presentations of food. Rats first received treatments of response-independent food or response-dependent food. Response-independent subjects then experienced one of the following treatments: inescapable shock in pairs and allowed to aggress, inescapable shock in pairs with no aggression, or no shock. All animals then were tested for learning in a straight runway. Subjects that were allowed to aggress and "won" ran in the runway the same as did the response-dependent animals who received no shock. Subjects that were allowed to aggress but "lost" ran more slowly in the runway than did the winners, and the losers level of performance was similar to that of the animals who were shocked in pairs but were not allowed to aggress. Successful aggression prevents the development of learned laziness, but unsuccessful aggression does not.

COGNITIVE MAPPING: A SITUATIONAL PERSPECTIVE. Angelique Gavin\*, Dept. of Psychology, Old Dominion Univ., Norfolk, VA 23508.

Subjects representing three different cohorts; children ( $\bar{x}$  age= 10), young adults ( $\bar{x}$  age= 33.4), and elderly adults ( $\bar{x}$  age= 71.1); were asked to design the "ideal" town for their own cohort and for the other two cohorts.

Multidimensional scaling analyses allowed for cross-generational comparisons of the three age-specific maps. Implications for urban planning are considered.

PROMOTING SAFETY ISSUES ON A UNIVERSITY CAMPUS. Christina L. Hadley, Kim Key\*, Helen P. Chambers\*, Brian Kramer\*, Dept. of Psychology, VPI&SU, Blacksburg, VA 24061. Using a field study approach, individuals representing different divisions and departments of a large state university were approached and interviewed. There were two primary purposes for these interviews: (1) to determine what steps the specific individual, division, or department had already taken in response to a nationwide concern for safety belt use, and (2) to identify what steps groups could take to promote campus-wide, division, or department use. A group's available resources and important constraints were identified for each respective interviewee. Ideas were generated and then evaluated in terms of their feasibility. Support was given to help implement specific strategies in some of these groups (the school newspaper, the intramural office, and the State Motor Pool). A student group (Students Organized for Safety) was formed to help with the interviews and to develop a manual on possible safety belt policy changes in a large-scale university. This manual can be used by other universities and organizations to promote safety belt use.

POWER, PERCEIVED CONTROL, AND PERCEIVED FREEDOM, AS INDICATORS OF MARITAL SATISFACTION OVER TIME. Lee M. Handeland, & Louis H. Janda\*, Dept. of Psychology, Old Dominion Univ., Norfolk, Va. 23508. This cross-sectional, exploratory study surveyed married individuals and married couples to determine if people's attitudes toward their marriage changed as a function of how long they had been married, attempted to determine the correlation of husband's and wife's reported marital satisfaction, and looked at the concept of perceived control and perceived freedom as related to marriage satisfaction. Measures used were the Marital Satisfaction Scale (Roach, Frazier, and Bowden, 1981), the Decision Making Scale (Centers, Raven, & Rodrigues, 1971), and a Marriage Freedom Scale designed for this study. Results of an overall Analysis of Variance did not find a significant effect for years of marriage and marital satisfaction on any of the scales. However, further analysis of the data showed significance in sub-areas. Correlation between married couple's response to the Marital Satisfaction scale were found to be similar to the findings of earlier studies.

SOME EFFECTS OF CAUDATE NUCLEUS LESIONS ON FORCE EMISSION IN RATS DURING A FIXED-RATIO TASK: A PRELIMINARY REPORT. William T. Hayes\* and John V. Harrell, Dept. of Psych., Hampden-Sydney Col., Hampden-Sydney, Va. 23943. The basal ganglia are believed to contribute significantly to the initiation of voluntary movement and control over sustained movement that requires substantial sensory input for precise performance. As a sequel to a previous study we have looked at effects of basal ganglia damage on a task of a more ballistic nature, requiring less sensory feedback for performance. Rats were given either bilateral caudate nucleus lesions (CN) or bilateral control lesions in parietal cortex (PC). Lesion effects were observed upon an FR-5 task. The task required that the rat make forelimb paw presses above 20 g of force upon a force transducer to advance the fixed-ratio counter. CN subjects had difficulty reestablishing responding postoperatively and, as indicated by strip chart recordings, their preoperative pattern of responding was altered during the initial postoperative sessions. Subsequently, most CN response parameters approached preoperative levels. PC's were essentially unaffected. (Supported by an H-SC faculty grant)

TRANSFER OF EFFORT ACROSS INSTRUMENTAL TASKS AND APPETITIVE REINFORCERS. Robert T. Herdegen, III, David P. Steinke, Dept. of Psych., Hampden-Sydney Col., Hampden-Sydney, VA 23943, & Laura Y. Theis, Dept. of Psych., Longwood Col., Farmville, VA 23901. The amount of required effort for the reinforced performance of one instrumental task can influence the vigor with which other instrumental responses are performed, known as the "transfer of effort effect" (Eisenberger, Terborg, & Carlson, 1979). For example, requiring several traversals of a runway for each food pellet (high effort) produces a higher rate of sub-sequent lever pressing for food than a single runway traversal for each food pellet (low effort). The present experiment studied the degree to which effort transfer will occur between behaviors maintained by different appetitive reinforcers. Two groups of water-deprived rats were trained to perform a lever-press-type operant response for water reinforcement on continuous reinforcement (Low Effort) or on FR25 (High Effort). Control group subjects were yoked to High Effort rats, receiving the same pattern and number of reinforcements but with no response contingency. After operant training, all subjects were switched to food deprivation and given four sessions of free-operant runway response training. Round-trip traversals of a runway were reinforced with food pellets on CRF. High Effort rats performed significantly more runway responses than Low Effort rats. Control rats were intermediate in their level of performance and did not differ from the other groups. Measures of the force of responses in the training task also show a relationship to responding in the runway. The results are consistent with Eisenberger's "learned effort" hypothesis, and the implications for human performance are discussed. (Supported by Hampden-Sydney Col. Faculty Research Grant.)

THE EFFECTS OF BIRTH ORDER ON ACHIEVEMENT MOTIVATION. Amy L. Herron, Dept. of Psychology, Old Dominion Univ., Norfolk, VA 23508. The relationship between birth order and achievement motivation was explored using the TAT as a measure of achievement motivation. Subjects consisted of 12 persons in each of the following categories: first offspring, later offspring, and only offspring. An Analysis of Variance was performed on the data. No significant differences were found between the three groups. Results indicate that one's ordinal position in the family has no effect upon his or her motive to achieve.

SAFETY BELT USE AT CORPORATE LOCATIONS: A LONG-TERM FOLLOW-UP. James M. Jeweler\* & Thomas D. Berry\* Dept. of Psychology, Virginia Tech, Blacksburg, VA 24061. This project assessed the long-term impact of a variety of incentive-based programs and awareness sessions on shoulder belt use at three corporate locations in Southwest Virginia. The data indicate that all procedures resulted in increased shoulder belt usage among employees. However, follow-up observation indicated that shoulder belt use decreased following withdrawal of the interventions. The influences of demographic variables such as gender and job status and maintenance issues are discussed.

EFFECTS OF IBOTENATE LESIONS OF THE CA1 HIPPOCAMPAL CELL FIELD ON ACQUISITION OF COMPLEX PLACE AND CUE TASKS IN THE RAT. L. S. Johnson and L. E. Jarrard, Dept. of Psychol., Washington & Lee Univ., Lexington, Va. 24450. Recent research indicated that postischemic rats with resulting brain lesions located primarily in the CA1 cell field of the hippocampus suffered a persistent working memory (WM) impairment in acquisition of a spatial task. In the present experiment, 12 Sprague-Dawley rats were divided into a control group (operated and unoperated), and an experiment group (N=8). Selective ibotenate lesions of CA1 were followed by acquisition of complex place and cue tasks (radial maze, 4 out of 8 arms baited). Results indicated that in the place task (that requires use of extra-maze cues), CA1 animals were initially impaired both in reference memory (RM) and in WM, but recovered after several trials to be indistinguishable from controls. In the cue task (that requires use of intra-maze cues), CA1 animals were unimpaired in WM, and showed a facilitation of RM. Implications of these results for current theorizing will be discussed.

## ALCOHOL CONSUMPTION AS A FUNCTION OF TYPE OF DRINK: MIXED DRINKS VS. BEER.

Kimberly L. Key\*, Fredrick M. Streff\*, & Michael J. Kalsher\*, Dept. of Psychology, Virginia Tech, Blacksburg, VA 24061. The veracity of the findings of a provocative study conducted by Berger and Snortum (1984) was studied. In a national telephone survey, these researchers found that individuals reported getting drunker on beer than on mixed drinks. However the results of the Berger and Snortum study were based on self-report. The present study examined actual drinking rates and preferences among students at two fraternity parties, and assessed blood alcohol concentration (BAC) when students arrived at the party and when they departed. Each student was allowed unlimited access to either mixed drinks or beer. Subjects were 200 (123 male-77 female) and 106 (74 male-42 female) students. During the first party, 97 beer drinkers consumed approximately 500 cups (100 cups/hr) whereas, 103 mixed drink drinkers consumed approximately 275 cups (55 cups/hr) of their respective beverages. Mean exit BAC for beer drinkers was .04 compared to .01 for mixed drink drinkers. During the second party, 66 mixed drink drinkers consumed approximately 377 cups (75 cups/hr) compared to 40 beer drinkers who consumed approximately 250 cups (50 cups/hr). Mean exit BAC for mixed drinkers was .05 compared to .07 for beer drinkers.

## THE EFFECT OF LABELING ON CONSUMPTION OF REGULAR, LIGHT, AND LOW ALCOHOL BEERS.

Kimberly Kirwan\*, Michael J. Kalsher\*, Galen R. Lehman\*, & Nason W. Russ, Dept., of Psychology, Virginia Tech, Blacksburg, VA 24061. Differences in consumption of regular, light, and low alcohol beers were observed at fraternity parties when the beers were labeled and when they were unlabeled. Drinking rates and beverage preference per individual were assessed for Budweiser (3.7% alcohol), Bud Light (2.8% alcohol), and LA by Anheuser Busch (1.7% alcohol). Following a blind taste test using all three beers, subjects were allowed unlimited access to the three types of beers. During the first party (labeled condition, N=371) the three types of beers were clearly labeled. Despite the fact that subjects showed no significant differences in taste preference across the three types of beer, approximately 1,000 cups (200 cups/hr) of Bud Light were served as compared to 725 cups (145 cups/hr) of Budweiser. Less than 50 cups (10 cups/hr) of LA beer were served throughout the party. At the second party (unlabeled condition, N=158) beer types were labeled A, B, or C. Drinking rate data indicated a more similar consumption pattern for the three types of beer. Approximately 450 cups (90 cups/hr) of Budweiser, 350 cups (70 cups/hr) of Bud Light, and 250 cups (50 cups/hr) of LA were served.

LEARNING DISABILITIES: BRAIN-BEHAVIOR RELATIONSHIPS  
AND IMPLICATIONS FOR EDUCATIONAL PROGRAMMING

James W. Kuhns, James Madison University, Harrisonburg, Va.

Approximately one-third of the children who evidence learning difficulties do so because of central nervous system dysfunction. The dysfunctional system(s) may involve one or more of the information processing systems of the central nervous system. A child's information processing strengths and weaknesses can be identified by a psychologist who is skilled in administration and interpretation of neuropsychological evaluation procedures.

The child's information processing strengths should be emphasized in the formulation and implementation of an individualized educational program. If this is done, the learning disabled child learns how to acquire information and academic skills in an idiosyncratic manner. Once the child has learned to acquire information and academic skills in her/his individualistic manner, s/he often can be transferred to a mainstream classroom program. The child will continue to need the part-time assistance of a teacher who specializes in learning difficulties in order to translate the classroom presentation/textbook information into a format which s/he can process meaningfully. With this type of individualized educational programming the child may achieve success.



DIRECT VS. INDIRECT REWARDS FOR PROMOTING SAFETY BELT USE ON A UNIVERSITY CAMPUS. Joanne E. MAC, Michael J. Kalsher\*, & James R. Rudd\*, Dept. of Psychology, Va. Tech, Blacksburg, VA 24061. This study assessed the impact of two large-scale incentive based programs designed to increase shoulder belt use on the Va. Tech campus. The direct incentive program (Seatbelt Sweepstakes) was conducted during 3 consecutive quarters of the 1983-84 academic year. Twenty-two campus police officers recorded the license plate numbers of vehicles with drivers wearing a shoulder belt, and from these numbers 10 raffle winners received gift certificates donated by community merchants. In this program, eligibility for the lottery was contingent upon being seen wearing a shoulder belt. Faculty & staff use increased as a result of the program, whereas student use increased only slightly. The indirect incentive program (Pledgecard Sweepstakes) occurred during the Spring & Fall academic quarters of 1985. In this program, 18,000 pledgecards were distributed: 9,000 on windshields of cars parked on campus, and 9,000 next to pledgeboxes located throughout campus. Pledgecards consisted of 2 sections: a stub which became the lottery entry, and a hang tag to be placed on the rearview mirror of their car. In this program, eligibility was contingent upon simply "pledging" to buckle up. Shoulder belt use among those who pledged increased from 40.2 to 59.8 & 41 to 59 percent for spring and fall quarters.

THE OVERLOOKED FACTOR: NEGATIVE SIDE EFFECTS OF QUITTING SMOKING. Steven Malone, Jay Skidmore\* & Nason Russ, Dept. of Psy., Va Tech, Blacksburg, VA 24060. Stop smoking groups are predicated on the belief that the client will feel better and live longer after quitting. This study reports on the symptoms experienced by 30 individuals after participating in a smoking cessation group. Each person participated in an 8 week group which used behavioral, brand switching and cognitive imagery techniques. Commonly reported symptoms include lack of concentration at work, inability to relax, headaches, and irritability with partner, friends and coworkers. The results are discussed in terms of the need for clinicians to inform clients of the immediate costs as well as the many benefits of quitting smoking.

Field Sobriety Tests: Protection for the Barkeep and the Party Giver. Julie Rockas\*, Fredrick M. Streff\*, Nason W. Russ, Dept. of Psychology, Virginia Tech, Blacksburg, VA 24061. During an annual spring event (Sigma Chi Derby Day) at which alcohol was served, 280 college students were given field sobriety tests and had their blood alcohol content (BAC) assessed. Four field sobriety testes were evaluated. The ruler drop test correctly categorized 57% of the subjects into drunk or sober categories based on BAC. A test in which subjects were required to count backwards by threes correctly classified 68%. A test of eye nystagmus correctly categorized 75%, and the best test was the one leg stand, correctly categorizing 84% of the subjects. The rates of false positive and false negative predictions of impairment will also be provided. Implications of these findings for party givers and barkeepers will be discussed.

YOU CAN LEAD A STUDENT TO LOW-ALCOHOL BEER, BUT HOW DO YOU MAKE HIM DRINK? Nason W. Russ & E. Scott Geller, Dept. of Psychology, Virginia Tech., Blacksburg, Va. 24061. Low-alcohol (LA) beer allows drinkers to reach lower blood-alcohol levels while still consuming their usual amount of beer. If LA beer were used regularly by college students, it could reduce the likelihood that students will drive drunk. When given a "blind" taste test prior to a party, students showed no clear preference for Budweiser, Bud Light, or Low-alcohol (LA) beer. However, once inside the party, they drank significantly less LA beer. General strategies are discussed for improved marketing interventions which might help LA beer impact on drunk driving among college students.

BEHAVIORAL EFFECTS OF NEUROTOXIN LESIONS OF THE SUBSTANTIA NIGRA. M. Christopher Talley, Jeffrey S. Mandak, John R. Carder\*, and Leonard E. Jarrard, Dept. of Psych., Washington & Lee Univ., Lexington, Va. 24450. In order to study the possible involvement of the substantia nigra (s.n.) in motivation, and more specifically the dopaminergic cells that project from the area, bilateral lesions of s.n. were made either with 6-hydroxydopamine (6-HD), a neurotoxin specific to dopaminergic and noradrenergic cells, or ibotenic acid (IBO), a toxin that destroys all cells in the injected area. The 18 rats lived in the Activity, Eating, and Drinking System (AED), and these behaviors were continuously monitored throughout the day and night. After the behaviors stabilized, the animals were divided into 4 groups (6-HD, IBO, operated, unoperated), and the operations were carried out. It was found that the IBO lesions significantly increased activity and altered eating, whereas the 6-HD lesioned animals and controls did not exhibit these changes. The data are interpreted as supporting the hypothesized existence of a functional cholinergic system within the s.n., and suggest that the observed behavioral changes are not a result of damage to the dopaminergic system.

EFFECT OF COUNSELOR SEX AND BEHAVIOR ON EXPECTATIONS ABOUT COUNSELING. Christine O. Work, Dept. of Psychology, Old Dominion Univ., Norfolk, Va. 23507. Impact of counselor sex and personality on female undergraduates' expectations about counseling was investigated. Ss read a description of the personality and counseling style of a male or female Nurturant, Model, or Critic counselor (after Apfelbaum, 1958) to whom they had been "assigned". Ss then completed an Expectations about Counseling questionnaire consisting of 17 subscales subsumed under four scales concerning Client Attitudes and Behaviors, Helper Attitudes and Behaviors, Helper Characteristics, and Process and Outcome. Multivariate analysis of variance (MANOVA) of the four scales revealed significant main effects of sex and of personality for Counselor Attitudes and Behaviors; no significant effects were seen for the other three scales. MANOVA of the 17 subscales revealed significant main effects of personality for attractiveness, directiveness and nurturance and of sex for trustworthiness, and significant interactions between sex and personality for empathy. No significant overall effects were seen ( $p < .05$ ). The findings suggest that counselor variables were perceived as such by Ss, but had no significant impact on expectations regarding other facets of counseling.

## Statistics

VARIABLE TIME DELAY CONTROL CHARTS. Raid W. Amin, Marion R. Reynolds, Jr. and Jesse C. Arnold, Department of Statistics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. Control charts are usually applied to control a production process by taking samples from the process at fixed time intervals. Control charts with variable time intervals between samples are considered, where the interval until the next sample depends on the perceived level of quality at the previous sample. The sampling interval will be long when quality appears to be high and short when quality appears to be low. Properties such as the average run length and the variance of the run length are developed for variable time delay Shewhart and Cusum charts. A Markov chain approach is utilized to approximate the average run length and the corresponding variance for the Cusum charts. Numerical computations show that the variable time delay control charts are considerably more efficient than the corresponding fixed time delay control charts.

ON THE APPLICATION OF AIC TO BIVARIATE DENSITY ESTIMATION, NONPARAMETRIC REGRESSION AND DISCRIMINATION. Taskin Atilgan,\* BMDP Statistical Software, Westwood Blvd., Los Angeles, Calif. 90025. Some simple data analytic procedures are available for bivariate nonparametric density estimation. If we use a linear approximation of specified basis functions then the coefficients can be estimated by the EM algorithm, and the number of terms judged by Akaike's information criterion. The method also yields readily compatible approaches to nonparametric regression and discrimination. Tukey's energy consumption data and a psychological test for 25 normal and 25 psychotic patients are reanalyzed and the current methodology compared with previous procedures. The procedures offer many possible applications in the biomedical area, which are discussed in Sections 5 and 6, e.g., it is possible to analyze noisy data sets in situations where structured regression techniques would typically fail.

COMPARISONS OF ALTERNATIVE NON-NESTED TESTING PROCEDURES. Laura L. Bauer & Oral Capps, Jr., Dept. of Statistics, Va. Polytechnic Inst. & State Univ., Blacksburg, Va. 24061. The choice of the most appropriate functional form for a regression model often necessitates the testing of non-nested hypotheses. Many asymptotically valid procedures exist for testing such models, but much needs to be learned about their small sample properties. Analytically, the finite sample distribution of only one of the tests is known. Thus, through the use of simulation studies, information will be gathered regarding the relative usefulness of these procedures under various distributional assumptions on the disturbance terms and for varying sample sizes. Resulting guidelines for the practical application of these procedures will then be employed based on demand analyses using actual household expenditure data.

THE EFFECT OF MULTIVARIATE NONNORMALITY ON THE PROBABILITY OF CHOOSING THE CORRECT NUMBER OF FACTORS USING AIC, CAIC, AND THE  $L_2$  MATRIX NORM. Hamparsum Bozdogan and Donald E. Ramirez, Dept. of Mathematics, Univ. of Va., Charlottesville, Va. 22903. In maximum likelihood factor analysis, the multivariate normality is often assumed for the variables. In practice it is very difficult to justify this assumption for a large number of variables. Therefore, this paper studies the popular maximum likelihood orthogonal factor model and the effect of multivariate nonnormality on the probability of choosing the correct number of factors using Akaike's Information Criterion (AIC), CAIC, and the Euclidean  $L_2$  Matrix Norm procedures. A large-scale Monte Carlo study is carried out for an orthogonal factor model with a known number of factors under the multivariate normality assumption, and the probability of choosing the actual number of factors is determined. The same simulated data tests are then marginally skewed, and the effect of nonnormality on the probability of choosing the correct number of factors is studied. The Box-Cox transformation of data to "near" multivariate normality is introduced and the skewed data sets are transformed to recover the probability of choosing the actual numbers of factors.

TESTS OF THE PARALLELISM OF SEVERAL REGRESSION SURFACES BASED ON RANK-ORDER ESTIMATES. Ching-Yuan Chiang, Dept. of Math. & Computer Sci., James Madison Univ., Harrisonburg, VA. 22807. We study a class of Wald-type tests for testing the parallelism of several regression surfaces. The tests, based on a quadratic form in rank-order estimates of regression parameters, are asymptotically distribution-free. These tests are compared with the classical normal theory test and the general likelihood ratio test as well as aligned rank-order tests for the same problem; the asymptotic relative efficiencies are given, and the asymptotic (Wald) optimality is discussed.

CONFIDENCE INTERVAL ABOUT THE RESPONSE AT THE STATIONARY POINT OF A RESPONSE SURFACE. V. M. Chinchilli, W. H. Carter, Jr., T. J. Breen and E. D. Campbell, Dept. of Biosta., Va. Commonwealth Univ., Richmond, Va. 23298. The response at the stationary point of a quadratic response surface can be expressed as a function of the model parameters. We have used a method due to Rao to construct a conservative confidence interval about the mean response at the stationary point. The computational effort associated with constructing such an interval is excessive. We propose the use of the delta method to construct an asymptotic, non-conservative interval about the mean response at the stationary point.

EXAMINATION OF RESIDUALS IN THE GMANOVA MODEL. Vernon M. Chinchilli, Ph.D., Asst. Professor, Dept. of Biostatistics, Box 32, Medical College of Va., Va. Commonwealth Univ., Richmond, Va. 23298. The statistical analysis of the GMANOVA model has received much attention in the statistical literature since its introduction by Potthoff and Roy (1964, Biometrika 51, 313-326). This report concentrates on examining various ways to estimate the random errors (residuals) from such an analysis. In particular, BLUS residuals, as introduced by Theil (1965, JASA 60, 1067-1079) are defined for the GMANOVA model. Finally, a numerical example is presented.

ANALYSIS OF WITHIN- AND ACROSS-SUBJECT CORRELATIONS. Sung C. Choi and Vernon M. Chinchilli, Department of Biostatistics, Medical College of Va., Richmond, Va. 23298-0001. In some fields of applications, response variables are measured on  $k(k>1)$  independent samples for each experimental subject. For this type of situation, within-subject and across-subject correlation matrices are defined and methods of analysis are discussed. The maximum likelihood estimators for the two different correlation matrices are obtained, and the exact test for within-subject correlation and two approximate tests for across-subject correlation are proposed. Simulation studies suggest that the estimators are satisfactory and that the two approximate tests are adequate although one of them can be overly conservative. Other properties of the estimators and the tests are discussed.

DISCRIMINANT ANALYSIS OF SPECTROPHOTOMETRIC VARIABLES OF PROTEINS FROM PLASMA SAMPLES OF CANCER, HEART, AND CLINICALLY NORMAL PATIENTS. Germille Colmano, L.M. Evans,\* and C.D. Sargent,\* VA-MD Regional College of Veterinary Medicine, VPI & SU, Blacksburg, VA. Amino acids in three pools of proteins of blood plasma have spectrophotometrically measurable variables indicating distinguishable patterns, separating clinically healthy from cancer and heart patients. Analysis of variables and some of their ratios have clearly separated the cancer from the heart patients and the normals. The big question relates to our capability, first to relate the canonical functions to specific clinical traits, and then to account for them in their predictive value.

A RIGOROUS DERIVATION OF AIC IN A GENERAL MODELLING CONTEXT WHICH REVEALS SOME OBSTACLES TO MODEL COMPARISON. David F. Findley,\* Bureau of the Census, Washington, DC 20233. A formula will be derived which precisely describes the large-sample behavior of the mean of the log-likelihood ratio of two not necessarily nested m.l.e. models for discrete or continuous i.i.d. data, or, more generally, of conditional distribution models associated with such data. The models need not encompass the true distribution. The formula and its generalizations permit a rigorous analysis of the large-sample bias properties of Akaike's AIC criterion in some very general contexts. The analysis suggests that the effectiveness of this criterion, and of other model comparison procedures, will be influenced by differences between the support of the true underlying probability measure and the supports associated with the fitted models, and by whether or not the latter change with the model parameters. These difficulties will be illustrated with a comparison problem provided by Wolfgang Härdle concerning two binary response curve models used for automobile side-impact accident data.

TOPICS IN THE ANALYSIS OF REPEATED MEASUREMENTS. Donald R. Jensen, Va. Polytechnic Institute and State University, Blacksburg, Va. 24061. This study is concerned with the analysis of repeated scalar and vector measurements. Alternative models are considered for the dependencies among successive observations within subjects, and analytical methods are identified as appropriate for these models. Companion procedures are given for multiple comparisons and for other nonstandard tests found useful in practice. Emphasis is given to the validity and efficiency of the several procedures considered. Nonparametric and robust aspects of relevant normal-theory tests are discussed with reference to the analysis of repeated measurements.

ON THE CORRELATION BETWEEN F-RATIOS. Robert E. Johnson, Department of Math. Sciences, Virginia Commonwealth University, Richmond, Virginia 23284. The coefficient of correlation between noncentral F-ratios sharing a common denominator is given. The correlation between doubly dependent F-ratios is shown to be the correlation between singly dependent F-ratios times a function of the correlation between the F-ratios' numerators. The correlation is positive if at least one of the noncentrality parameters is zero, but may be zero or negative if both noncentrality parameters are positive. These relationships are viewed geometrically. Examples are taken from the ANOVA in the unequal-cell-sizes case.

VARIABILITY REDUCTION THROUGH SUBVESSEL CUSUM CONTROL. Kimberly J. Kearns \*, Dept. of Statistics, Va. Polytechnic Inst., Blacksburg, Va. 24061, & James M. Lucas\*, E.I. DuPont de Nemours & Co., Wilmington, De. 19898. When a production process involves nesting, continuous reduction in product variability can be realized through the use of subvessel CUSUM control schemes. An analysis of variance is used to determine that quality control should be implemented at the subvessel level to obtain the largest reduction in product variability. A discussion of a design of a CUSUM scheme for subvessel control illustrates that often such a CUSUM scheme will require different parameter values than CUSUMs used for vessel control. This is a case study illustrating an interesting application of CUSUM control on a nested production process.

ESTIMATION BASED ON MAXIMA OF RANDOM VARIATES: AN AID TO EVALUATING THE LIGHTNING THREAT TO AIRCRAFT. Larry D. Lee\*, MS 130, NASA LaRC Hampton, Va. 23665. To ensure that the largest, or worst-case pulse that can be detrimental to electronic systems aboard advanced aircraft is recorded, the F-106 direct strike lightning research employs peak detectors which record only the largest,  $W_i$ , among the individual peak rates-of-change of currents and fields generated as the result of  $z_i$  strikes during the  $i$ th flight. Since only the largest peak readings are observable, it is not possible to obtain relative frequency estimates of the underlying distributions in the usual manner directly from peak detector data. A likelihood function based on the data  $(z_i, w_i)$ ,  $i=1,2,\dots,n$  and the assumption that peak rates have a common distribution is derived from the following basic relation:  $\Pr\{W \leq x | z\} = \{H(x)\}^z$ . Asymptotic properties of the maximum likelihood estimators are established and a computationally feasible form of the estimating equations is derived. Besides aiding an evaluation of the lightning threat to aircraft, the method seems a useful way to analyze other stochastic phenomena involving maxima.

MULTIVARIATE NICHEMETRICS. Ruey-Pyng Lu, Dept. of Stat., Hollins College, VA 24020, & Eric P. Smith, Dept. of Stat., Va. Polytechnic Inst. and State Univ., Blacksburg, VA 24060. The niche is an important ecological concept. Recent interest has focused on measuring niche parameters, particularly the overlap between the niches of two similar species. Several measures of niche overlap (similarity) are derived assuming multivariate normality and heterogeneous variance-covariance matrices. The assessment of the measures of similarity are carefully investigated. Jackknife and bootstrap methods were used to estimate the precision and accuracy of the currently used measures. The factors influencing accuracy and precision are: sample size, dimension, the determinants of the covariance matrices and the mean difference. Monte Carlo simulation was used to assess the effects of these factors.

A CLASS OF DESIGNS WITH RESTRICTED RANDOMIZATION. David D. Morris and Klaus Hinkelmann, Dept. of Statistics, Va. Polytechnic Institute and State Univ., Blacksburg, Va. 24061. Shifts in response are sometimes likely to occur in the borders of designs. Design random variables are used to determine the impact of 'border effects' on the usual sums of squares, treatment estimates, and treatment differences. The randomized complete block, Latin square, and split plot designs in particular are examined. Alternative randomization schemes are examined for robustness to the border effects. In order to compare designs, relevant criteria are needed. Possible comparisons among unbiased designs could be based upon mean squared error of treatment estimates and/or variance of treatment differences.

PRINCIPAL COMPONENTS ANALYSIS OF HEAT-INDUCED DEFORMATIONS OF SPACE STRUCTURES. James R. Schiess and Robert H. Tolson, NASA Langley Research Center, Hampton, VA 23665. An important problem in the design of large space structures is the control of deformations caused by solar heating. This is an especially critical problem for large space antennas which may deviate significantly from a parabolic shape due to uneven heating of structural members. Principal components analysis is presented as a technique for analyzing the significant components of the structural deviations. The method is applied to a simple cubical structure consisting of aluminum members. Two methods of minimizing the deviations based on the principal components analysis are presented.

METRIC CONSIDERATIONS IN CLUSTERING: IMPLICATIONS FOR ALGORITHMS. Stanley L. Sclove,\* Dept. of Information and Decision Sciences, Col. of Business Administration m/c 294, Univ. of Illinois at Chicago, Box 4348, Chicago, Ill. 60680-4348. Given measurements on  $p$  variables for each of  $n$  individuals, aspects of the problem of clustering the individuals are considered. Special attention is given to models based upon mixtures of distributions, esp. multivariate normal distributions. The relationship between the orientation(s) of the clusters and the nature of the within-cluster covariance matrices is reviewed, as is the inadequacy of transformation to principal components based on the overall (total) covariance matrix of the whole (mixed) sample. The nature of certain iterative algorithms is elucidated; variations which result from allowing different covariance matrices within clusters are studied.

PLANT EFFICIENCY AND INFLUENTIAL OBSERVATIONS. Bill L. Seaver, Dept. of Stat., Konstantinos P. Triantis\*, Dept. of IEOR, Va. Polytechnic Inst. & State Univ., Northern Va. Grad. Ctr., Falls Church, VA 22042. An empirical study of efficiency at the plant level, requiring production and financial data, was done using frontier production function and linear programming specifications. The production frontier models with different methodologies did not consistently flag the same observations as being efficient or inefficient. As a result, outlier diagnostics for the individual observations, and most importantly, for subsets of observations, were used to achieve a relative index of influentiality within the spectrum of efficiency. In addition, k-clustering methodology as a detection tool for influential subsets in regression highlighted the relative importance of the efficient and inefficient observations. These outlier diagnostic tests and clustering techniques consistently flag the same subsets of efficient and inefficient observations as the frontier models and also clarify ranking discrepancies among the production frontier model specifications.

ESTIMATING COMMON PARAMETERS OF GROWTH CURVE MODELS. Nariaki Sugiura\* and Tatsuya Kubokawa,\* University of Tsukuba, Sakura, Ibaraki 305, Japan. Suppose that we have two independent random matrices  $X_1 (p_1 \times N_1)$  and  $X_2 (p_2 \times N_2)$  having multivariate normal distributions with common matrix of unknown parameters  $\xi (q \times m)$  and different unknown covariance matrices  $\Sigma_1$  and  $\Sigma_2$  given by  $N_{p_1 N_1} (B_1 \xi A_1; \Sigma_1, I)$  and  $N_{p_2 N_2} (B_2 \xi A_2; \Sigma_2, I)$ , respectively. Let  $\hat{\xi}_1 (\hat{\xi}_2)$  be the MLE of  $\xi$  based on  $X_1 (X_2)$  only. When  $q = 1$ , necessary and sufficient conditions that a combined estimator of  $\hat{\xi}_1$  and  $\hat{\xi}_2$  has uniformly smaller covariance matrix than those of  $\hat{\xi}_1$  and  $\hat{\xi}_2$  are given. K-sample problem as well as one sample problem is also discussed. These results are extensions of those of Graybill and Deal (1959 Biometrics), Bhattacharya (1980 Ann. Statist.; 1984 Ann. Inst. Statist. Math.) to the multivariate case.

MODEL EVALUATION IN MULTIDIMENSIONAL SCALING. Yoshio Takane,\* McGill University, Montreal, Quebec, Canada H3A 2K6. Most of the psychometric models consist of three important submodels: the representation model, the error model and the response model. In multidimensional scaling (MDS) a distance model is used to describe (dis)similarity relations among stimuli (the representation model). The similarity relations represented by the distance model are then assumed to be error-perturbed in a specific way (the error model). Finally, the error-perturbed similarity relations are transformed into a specific form of the data (e.g., stimulus confusion probabilities, reaction times, etc.). The model for this transformation mechanism is called the response model. Within this framework model evaluation plays an important role. In this paper we demonstrate how the model evaluation plays an important role. In this paper we demonstrate how the model selection strategy based on AIC can be effectively used to identify the best combination of the submodels.

NONPARAMETRIC REGRESSION FOR CENSORED SURVIVAL DATA WITH RANDOM COVARIATES. Wei-Yann Tsai\* and John Van Ryzin,\* Brookhaven National Laboratory, Upton, N.Y. 11973, and Columbia University, New York, N.Y. 10027. Estimators for nonparametric regression models in the presence of right censoring are given by Doksum and Yandell (A Festschrift for Erich L. Lehmann (1983), 140-156, Wadsworth). A new extension of such nonparametric estimators to censored data is given and studied. The method consists of applying the ordinary nonparametric regression estimator to synthetic times, as suggested by Luergans (Univ. of Wisconsin Tech. Rept. 1984). Synthetic times are constructed by magnifying the gaps between successive order statistics. Strong consistency results, asymptotic distributions and confidence bands for nonparametric regression curves based on right censored data are derived. The estimator is compared with the nonparametric regression estimator proposed by Doksum and Yandell by means of the asymptotic variances. An example is illustrated by using the Stanford heart transplant data.

EMPIRICAL BAYES PROCEDURES IN TIME-SERIES-REGRESSION MODELS. Ying-keh Wu and Richard G. Krutchkoff, Dept. of Stat., Va. Polytechnic Inst., Blacksburg, Va. 24061. The empirical Bayes estimation procedure (EBE) for the coefficients in time series regression models is presented. Due to the uncontrollability of time series observations the explanatory variables (regressors) in each component problem vary unpredictably. An extension of the results of O'Bryan and Susarla (Communications in Statist., 1975) is established and shown to be a generalization of the results of Martz and Krutchkoff (Biometrika, 1969). Alternatively, the results of Griffin and Krutchkoff (Biometrika, 1971) on empirical linear Bayes estimator (ELBE) are extended and then applied to estimating the coefficients in the same time series models. Predictions using EBE and ELBE are also discussed.



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OFFICIAL PUBLICATION OF THE VIRGINIA ACADEMY OF SCIENCE

**Fall 1986**

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## Habitat and Diversity of Fishes of Selected Tributaries of Roanoke Creek, on the Virginia Piedmont

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### ABSTRACT

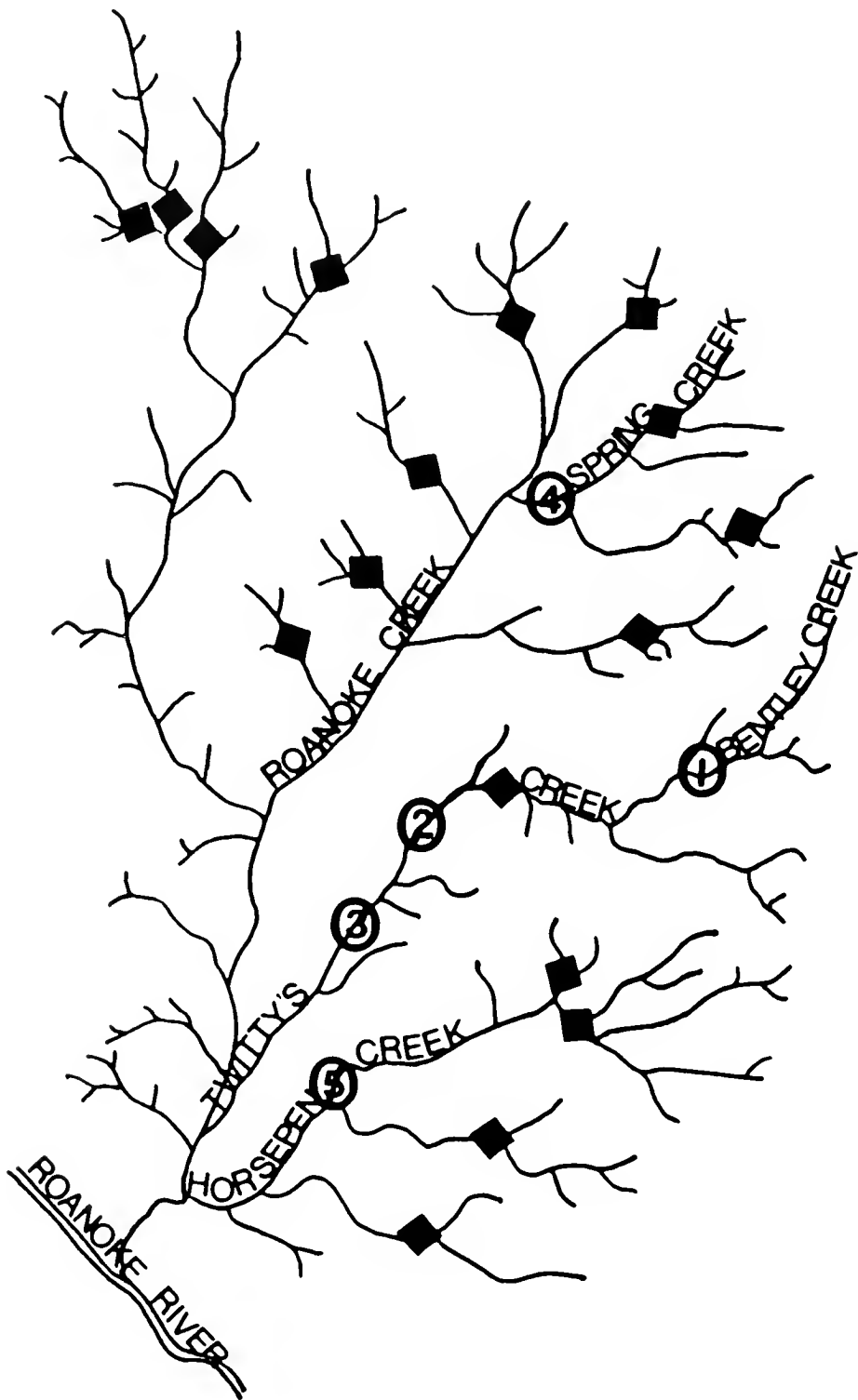
Fish populations were not greatly different in species composition in mature and channelized streams. Evenness diversity was generally greater in natural than channelized streams. Bluehead chub (Nocomis leptoccephalus) were generally present in much higher relative numbers in the channelized streams. These data serve as a baseline from which to evaluate future changes in species composition and abundance.

### INTRODUCTION

Roanoke Creek is a heavily channelized and impounded watershed that was part of the proposed site of the Southside Hydroelectric pump and storage project. Channelized sections and the many small impoundments are part of an overall flood control management program in this drainage. When the pump storage reservoir was first proposed, it was hypothesized that construction would cause changes in downstream water quality and in daily and seasonal stream flows which could subsequently cause changes in fish populations. In addition, it was hypothesized that both upstream and downstream movements of aquatic fauna would be affected by construction of the reservoir. In light of the many changes that could have resulted from project construction, we used data collected in another study to develop a representative list of fish currently occupying natural and channelized tributaries of upper Roanoke Creek. Subsequently, plans to build the reservoir were discontinued but the species information still serves as a useful reference point.

### DESCRIPTION OF THE STUDY AREA

Four streams--Twitty's, Bentley, Spring, and Horsepen creeks--in the upper Roanoke Creek watershed were selected for the present study (Fig. 1). Bentley Creek is 4.8 km long, 3-6 m wide, and averages 0.3-0.6 m deep. Substrate varies from bedrock to gravel and canopy coverage is complete. Twitty's Creek is 30.6 km long, 3-9 m wide, and averages 0.3-0.6 m deep. Substrate is primarily sand and gravel and canopy coverage is generally



**Figure 1.**

**The Roanoke Creek Drainage (Charlotte County) in the Virginia Piedmont. Sample sites are indicated by circled numbers. Damm sites are identified by squares.**

dense. In the present discussion, "Twitty's N" refers to natural sections of the stream, and "Twitty's C" to channelized sections. Spring Creek is 11.3 km long, 1.6-4.6 m wide, averages 0.3-0.5 m deep, and has a sand substrate and little canopy coverage. Horsepen Creek is 17.7 km long, 5-9 m wide, averages 0.3-0.5 m deep with a sand substrate and has a well-developed canopy. All creeks have a continuous flow that decreases in summer. Along all creeks there are channel modifications and flood retarding

structures; however, the streams at some of the individual sampling stations were not channelized (upper Twitty's Creek and Bentley Creek). The other sampling sites were located in channelized sections: Spring Creek was channelized in 1972, lower Twitty's Creek was channelized in 1969, and Horsepen Creek was channelized in 1965.

#### METHODS

Fish were collected quarterly for 2.5 years, beginning in June 1974. All fish were collected with a gas powered electroshocker, from three 30 m sections per station/per quarter. Block seines (3/8 inch mesh) were placed at the upper and lower end of each section to limit the movement of fish into or out of the sampling area. Most fish were identified, counted, and returned to the stream after each collection; some were retained for verification of identification by specialists. Overall average fish species abundance was determined per section over the entire study period.

Evenness diversity (Pielou 1966) was also determined for the fish community of each stream. The evenness diversity of a collection is maximal when the collection is composed of equal numbers of fish of each species; conversely, if most of the fish are restricted to only a few species, the evenness diversity is low. The nonparametric procedures of Friedman's Rank Sum test for randomized blocks, and its associated Multiple Comparison Test (Hollander and Wolfe, 1973) were used in statistical analysis.

Physical measurements and delineation of habitats were taken on the dates on which fish were sampled. The following definitions of pools and riffles of Hynes (1970) were used in the study: pools had an average width or length greater than the average width of the stream and were generally greater than 0.6 m deep; riffles had an average width or length less than the average width of the stream and were less than 0.3 m deep; and runs were intermediate, having an average width or length equal to the width of the stream and an approximate depth of 0.3-0.6 m. In determination of affinity of individual species for pools or riffles, runs were combined with pools.

#### RESULTS

Thirty-eight species from eight families were collected from the five locations (Table 1). Thirty species were primarily associated with pools, seven primarily with riffles, and one was collected in equal numbers in the two habitats. However, this statement must be tempered by the fact that there was significantly more area in pools (including runs) than in riffles (Table 2).

Channelization appeared to have an influence on species evenness diversity. Average evenness diversity within years was lower in the three channelized locations than in the two natural locations (Table 2). However, values in Horsepen Creek were only slightly lower than those in Twitty's N. Channelization also appeared to influence stream physical characteristics. Substrate composition seemed to show more small particle sizes in sites that had been channelized than in natural sites (Table 3). However, no pre-channelization data are available to substantiate that there were not similar differences among the sites prior to channelization. Bank and instream cover was lower on channelized streams than at natural locations. Channelized sites seemed to show successional changes over the study period, the least cover being on the most recently channelized site (Tables 4 and 5).

## DISCUSSION

The distribution of several speices of fish was limited. Five species were taken from one or two sites. (Ictalurus platycephalus, Ictalurus punctatus, Pomoxis annularis, Pomoxis nigromaculatus, and Perca flavescens). These species probably escaped from reservoirs and ponds in the drainage or had strayed from the Roanoke River.

Fish distribution was related to substrate and flow; the pools supported the most species. Factors which might lead to a greater number and more diverse group of fishes in the pools include: (1) absence of current in pools (Kendeigh, 1961), (2) increased diversity of macroinvertebrates and drift organisms and thus greater and more accessible supply of food in pools (Waters, 1968), (3) the greater amount of this habitat available. The latter factor is probably the major one.

The numbers of species were similar in all of the creeks although some sample stations were further downstream than others. Generally, the number of fish species increases with increased distance from the headwaters (Harrel and Dorris, 1968; Sheldon, 1968; Whiteside and McNatt, 1972). This increase in numbers of species has been attributed to (1) the addition of new and stable habitats with increased stream size (Whiteside and McNatt, 1972), and (2) decreased fluctuations and increased available habitat (Harrel and Dorris, 1968). However, in the Roanoke drainage this trend may be offset by the influence of stream alteration, which had occurred on all downstream sites sampled.

Channelization did not appear to influence the number of fish species present (species richness) but did appear to affect the abundance of some speices. Evenness diversity values were gennerally lower, although sometimes only slightly lower, in the channelized stream sections than in the natural sections (Table 2). The dominance of the fish fauna of altered sections by Nocomis leptcephalus was responsible for this low evenness diversity. In natural stream sections, evenness diversity values were generally higher, possibly as a result of greater habitat diversity. Substrate composition in natural sections consisted of sand, gravel, rubble, and rock; whereas substrates in channeled sections were primarily sand. Similarly, natural areas or old channelized areas had more instream cover in the form of undercut roots and rocks and denser canopies than more recently channelized sites.

## ACKNOWLEDGEMENTS

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Table 1. Distribution, abundance (average number per section) of fishes and habitat occupied (P = pools and R = riffles) in tributaries of the Roanoke Creek.

Species	Bentley Creek (1)*	Twitty's		Spring Creek (4)	Horsepen Creek (5)	Habitat
		Natural (2)	Channelized (3)			
<u>Dorosoma cepedianum</u> (Lesueur)	-	1.03	0.50	0.27	-	P
<u>Esox niger</u> (Lesueur)	0.75	0.87	1.17	1.39	1.03	P
<u>Esox americanus</u> (Lesueur)	-	0.40	0.60	0.35	0.19	P
<u>Erimyzon oblongus</u> (Mitchill)	3.83	1.20	1.47	1.59	-	P
<u>Hypentelium roanokense</u> (Lesueur)	-	-	0.20	6.66	0.10	R
<u>Catostomus commersoni</u> (Lacepede)	0.43	4.83	3.30	3.63	0.70	P
<u>Moxostoma erythrum</u> (Rafinesque)	0.08	3.23	8.23	1.60	1.86	P
<u>Campostoma anomalum</u> (Rafinesque)	0.08	2.33	0.27	0.90	-	R
<u>Clinostomus funduloides</u> (Girard)	0.08	2.23	0.50	0.40	0.23	P
<u>Nocomis leptocephalus</u> (Girard)	34.08	42.57	305.51	160.52	73.39	R,P
<u>Notropis analostanus</u> (Girard)	-	1.44	13.07	14.63	28.53	P
<u>Notropis ardens</u> (Cope)	-	48.57	16.91	10.73	10.73	P
<u>Notropis procne</u> (Cope)	2.90	22.26	88.82	0.56	33.99	P
<u>Notropis cerasinus</u> (Cope)	33.75	47.74	45.84	56.53	16.80	P
<u>Notemigonus crysoleucas</u> (Mitchill)	27.33	5.56	1.26	1.87	0.57	P
<u>Phoxinus oreas</u> (Rafinesque)	-	7.49	0.82	13.10	0.40	P
<u>Hybognathus requis</u> (Girard)	-	-	0.60	2.46	1.33	P
<u>Ictalurus platycephalus</u> (Rafinesque)	-	-	0.26	-	0.06	P
<u>Ictalurus nebulosus</u> (Lesueur)	0.73	0.59	3.47	1.21	1.70	P
<u>Ictalurus punctatus</u> (Rafinesque)	-	-	0.3	-	-	P
<u>Noturus insignis</u> (Richardson)	13.50	3.93	1.70	2.93	3.14	R
<u>Aphredoderus sayanus</u> (Gilliams)	0.15	0.06	0.03	0.03	-	P
<u>Micropterus salmoides</u> (Lacepede)	0.08	1.39	0.23	0.13	0.29	P
<u>Lepomis gibbosus</u> (Linnaeus)	4.93	3.27	0.83	4.90	2.94	P
<u>Lepomis cyanellus</u> (Rafinesque)	35.08	3.27	3.60	1.04	2.47	P
<u>Lepomis auriatus</u> (Linnaeus)	1.85	13.92	16.00	8.03	9.81	P

Table 1. Continued.

Species	Bentley Creek (1)*	Twitty's		Spring Creek (4)	Horsepen Creek (5)	Habitat
		Natural (2)	Channelized (3)			
<i>Leopomis macrochirus</i> (Rafinesque)	15.40	23.55	23.90	5.36	7.83	P
<i>Lepomis gulosus</i> (Cuvier)	-	1.23	1.10	0.20	0.83	P
<i>Centrarchus macropterus</i> (Lacepede)	0.08	0.03	0.12	-	0.06	P
<i>Pomoxis annularis</i> (Rafinesque)	-	-	-	-	0.07	P
<i>Pomoxis nigromaculatus</i> (Lesueur)	-	0.10	-	-	0.11	P
<i>Percia flavescens</i> (Mitchill)	-	-	-	-	0.17	P
<i>Etheostoma vitreum</i> (Cope)	-	0.23	1.04	0.86	2.11	P
<i>Etheostoma nigrum</i> (Rafinesque)	5.98	12.30	24.00	18.90	9.09	R
<i>Etheostoma flabellare</i> (Rafinesque)	45.85	35.73	3.61	15.32	2.54	R
<i>Etheostoma collis</i> (Girard)	-	0.26	0.37	0.70	-	P
<i>Percina crassa roanoka</i> (Jordan and Jenkins)	-	0.07	1.27	0.29	0.69	R
<i>Percina peltata</i> (Stauffer)	-	0.03	0.96	0.30	0.13	R
Total species 38	21	32	35	32	32	

\*Station number (Fig. 1) in parentheses.



Table 2. Physical and biological characteristics of five stations in the Roanoke Creek drainage.

Creek	Station number	Area in square meters			Ratios			Evenness diversity	
		Pools	Runs	Riffles	Pool/riffle	Pool/run	Run/riffle	Yr. 1	Yr. 2
Bentley	1	5330	2970	1756	3.0/1	1.8/1	1.7/1	0.712	--*
Twitty's natural	2	9186	2352	2685	3.4/1	3.9/1	0.9/1	0.690	0.768
Twitty's channelized	3	5926	6252	2860	2.0/1	0.9/1	2.2/1	0.520	0.666
Spring	4	390	3648	1170	0.3/1	0.1/1	3.1/1	0.413	0.568
Horsepen	5	6355	3780	850	7.5/1	1.7/1	4.5/1	0.564	0.706

\*Data collected from Bentley Creek during year one of the study.

Table 3. Ranking of substrate composition of four stream sections in the Roanoke Creek drainage. The ordering from left to right is from lower to greater amounts of a particular substrate type. Continuous underlining indicates no significant differences ( $P<0.05$ ).

Substrate type	Multiple comparison test			
Clay	<u>Horsepen,</u>	<u>Twitty's N,</u>	<u>Spring,</u>	<u>Twitty's C</u>
Silt	<u>Twitty's N,</u>	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Horsepen</u>
Sand	<u>Twitty's N,</u>	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Horsepen</u>
Gravel	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Horsepen,</u>	<u>Twitty's C</u>
Rubble	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Horsepen,</u>	<u>Twitty's N</u>
Rock	<u>Twitty's C,</u>	<u>Horsepen,</u>	<u>Spring,</u>	<u>Twitty's N</u>

Table 4. Ranking of overstream cover for four stream sections in the Roanoke Creek drainage. The ordering from left to right is from lower to greater amounts of overstream cover. Continuous underlining indicates no significant difference in cover ( $P<0.05$ ).

Cover type	Multiple comparison test			
Herbaceous	<u>Horsepen,</u>	<u>Twitty's N,</u>	<u>Twitty's C,</u>	<u>Spring</u>
Woody 0-1.5 m	<u>Horsepen,</u>	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Twitty's N</u>
Woody 1.5-4.6 m	<u>Spring,</u>	<u>Twitty's N,</u>	<u>Twitty's C,</u>	<u>Horsepen</u>
Woody > 4.6 m	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Twitty's N,</u>	<u>Horsepen</u>

Table 5. Ranking of the four study sites in relation to the amount of instream cover. The ordering from left to right is from lower to greater amounts of instream cover. Continuous underlining indicate no significant differences in instream cover ( $P < 0.05$ ).

Cover type	Multiple comparison test			
Aquatic plants	No significant difference			
Woody plants	No significant difference			
Herbaceous plants	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Twitty's N,</u>	<u>Horsepen</u>
Logs and brush	No significant difference			
Undercut roots	<u>Spring,</u>	<u>Twitty's C,</u>	<u>Horsepen,</u>	<u>Twitty's N</u>
Undercut banks	No significant difference			
Rock	<u>Horsepen,</u>	<u>Twitty's C,</u>	<u>Spring,</u>	<u>Twitty's N</u>

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## **A Computerized Information Retrieval System For Small Biological Collections**

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### **Abstract**

The program was designed specifically for use in the University of Richmond Fish Collection, which has over 4000 cataloged entries. It is a basic linear recording system in Fortran 77 language that uses a similar format to that of the Collection manual catalog. The storage system is divided into primary and secondary files. Data storage headings in the primary file are genus, species, state, drainage, collection number, number of specimens, and catalog number. The secondary file includes detailed information on locality and collectors. The structure of the program permits input, retrieval, sorting, updating, and deleting of records. Only a minimal knowledge of computers is required to run the programs as the system is "user friendly."

### **Introduction**

The Association of Systematic Collections survey indicates that at present many files containing biological collections are in manual journals (Sarasan and Neuner, 1983). However, manual systems are not efficient for retrieval of information, as access to many categories, e.g. genus and species, is limited. A computer filing system, with capabilities of integrating and accessing many different categories simultaneously, makes specimen data much more available for research, inventory and loan processing. Computerized records are working successfully in several larger museum collections, e.g. the Smithsonian Institute of Natural History Museum (Sarasan and Neuner, 1983), but overall, museum collections have not taken advantage of the vast capabilities of computer systems. The following is a discussion of the information retrieval system implemented at the University of Richmond Fish Collection (over 4000 cataloged entries) and how this system will increase accessibility to the collection.

### **Procedure**

Sarasan and Neuner (1983) suggested a procedure to follow in installation of data base systems, and, in fact, the procedure we used was similar to it. The first step was an analysis of the existing manual system to determine its weaknesses, which included illegible handwriting, misspellings, and other errors that were not easily corrected once entered. In manual logs these errors must be scratched out or written over, making the manual difficult to read. More importantly, chronological ordering made retrieval of specific information pertaining to genera, species, or location of collections a laborious task. Additionally, a single storage system provided limited security for irreplaceable data.

After analyzing the problems encountered with the manual system it was determined the computer record storage would be a two-part data file with an efficient entry and retrieval system simple enough in format that personnel with limited training in computers could use with confidence (Fig. 1). FORTRAN-77 (Digital, 1980b) was selected as the language because of its appropriateness for filing programs, its compatibility with the VAX computer (The University of Richmond mainframe) and because we were more familiar with it than with other languages.

For easy cross reference between files information stored in computer files should be in a format that corresponds as closely as practical to that of the manual journal, which is kept with the fish collection and where the original recording of data takes place. To accomplish this two computer files were constructed. First, a primary linear data file was developed that listed genus, species, state, county drainage, date, number of specimens and catalog number. Second, a secondary file was created with information (e.g. collection sites and collectors names) that was associated with a primary file entry.

In the design of the primary file data entry and retrieval were considered together so as to ensure that once data were entered they could be readily located (Fig. 2). After evaluating various available filing systems a FORTRAN indexed filing system was found appropriate because of its compatibility with the phylogenetic classification system. Next, using mental models, flow charts, and computer manuals (Digital, 1980a; Digital, 1985) programs were developed to accomplish entry and retrieval. Later, other programs were devised similarly to achieve updating and deletion of data (Fig. 3). A set of programs was developed rather than one large program so as to reduce the complexity of the system and to allow for easy expansion of the systems capabilities by museum personnel.

Once the primary file system was completed a secondary detailed description file was developed, which could be accessed by a unique code (catalog) number assigned to each record in the primary file (Fig. 4). The whole program design required only minimal knowledge of computer operation by providing limited and easily followed instructions on the screen.

### Conclusion

The addition of the computerized management system will substantially improve the capability of the University of Richmond Fish Collection over that of the manual system alone. First, it provides new and better avenues for loan processing and documentation retrieval, making the collection more accessible to researchers at other institutions. Second, access to information and inventorying are both faster and easier. Third and most importantly, while this system eliminates the inherent problems in the manual system it provides a backup security system.

For small collections (< 10,000 entries) our system is at least as fast in data retrieval, less costly to implement, and easier for novices to use than other systems that are available on the market. As for the program's versatility, even though the format was developed specifically for the University of Richmond Collection, it is general enough to be functional for other fish collections without substantial change. With only minor column heading changes it can also be used in other biological collections, e.g. herbariums or insect collections.

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Thanks to John R. Hubbard, (Professor, Academic Computing Department) and Gilpin Brown (Academic Computing Technical Assistant), University of Richmond, for their assistance in developing the programs, and to Mrs. Sarah Lehman for typing the manuscript. The project was funded in part by a grant from the University of Richmond Undergraduate Research Committee.

PRELIMINARY RESEARCH

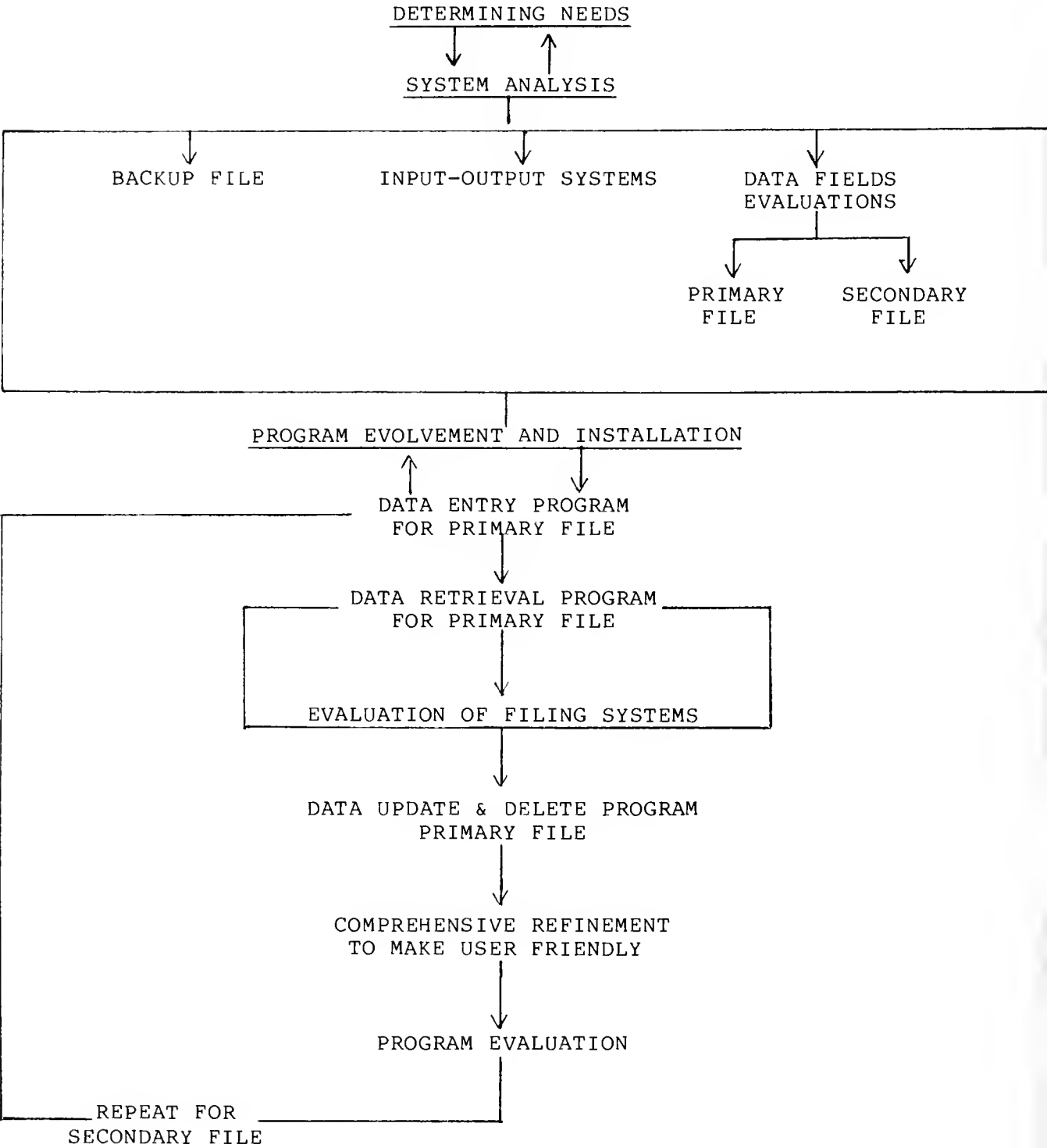


Figure 1.  
Flow chart for development of the program.

A. \$ RUN NEWREC.EXE  
 THIS PROGRAM ENTERS NEW RECORDS INTO THE FILE ICTHY.DAT.  
 ENTER NEXT RECORD IN THE FORM: 'GENUS' 'SPECIES' 'STATE ABBREVIATION'  
 'DRAINAGE' 'COUNTY' 'DATE' 'COLLECTION #' 'NUMBER OF SPECIMENS' 'CATALOG #'  
 EACH ENTRY SHOULD BE IN SINGLE QUOTES AND SHOULD NOT CONTAIN ANY OTHER TYPE  
 OF PUNCTUATION  
 PLEASE INCLUDE A BLANK BEFORE ANY GENUS NAME, AS SHOWN ABOVE  
 A COUNTY MAY ONLY HAVE THE FIRST ELEVEN LETTERS OF ITS NAME ENTERED  
 DATES SHOULD BE ENTERED USING THE FOLLOWING FORM: '2/16/85'  
 'NOTROPIS' 'PROCNE' 'VA' 'JAMES' 'FLUVANNA' '10/10/56' 'WSWVA22' '4 5' '0060'  
 ENTER NEXT RECORD IN THE SAME FORM AS ABOVE  
 IF THERE ARE NO MORE RECORDS, THEN TYPE  
 'END' '0' '0' '0' '0' '0' '0' '0' '0' '0'  
 '0' '0' '0' '0' '0' '0' '0' '0' '0' '0'

FORTTRAN STOP  
 \$

B. \$ RUN SEARCH.EXE  
 \*\*\*\*\*  
 \* MENU \*  
 \* \*  
 \* ENTER 1 FOR GENUS ENTER 5 FOR COUNTY \*  
 \* ENTER 2 FOR SPECIES ENTER 6 FOR DATE \*  
 \* ENTER 3 FOR STATE ENTER 0 FOR CATALOG NUMBER \*  
 \* ENTER 4 FOR DRAINAGE \*  
 \*\*\*\*\*

ENTER THE NUMBER CORRESPONDING TO THE  
 CHARACTERISTIC YOU ARE MOST INTERESTED IN  
 2

ENTER SPECIFIC INFORMATION YOU ARE LOOKING FOR  
 'PROCNE'

IF IT IS TRUE THAT YOU ARE ONLY INTERESTED IN ONE  
 CHARACTERISTIC ENTER ,TRUE, ,IF YOU ARE INTERESTED IN MULTIPLE ENTER ,FALSE,  
 T

GENUS	SPECIES	STATE	DRAINAGE	COUNTY	DATE	COLL. #	# SPECM	CATL.
-----	-----	-----	-----	-----	-----	-----	-----	-----
NOTROPIS	PROCNE	VA	JAMES	FLUVANNA	10/10/56	WSWVA22	45	0060
NOTROPIS	PROCNE	VA	JAMES	CUMBERLAND	10/10/56	WSWVA21	111	0081

END OF FILE OR NO SUCH FILE EXISTS  
 FORTTRAN STOP  
 \$

## Figure 2.

Commands and examples that appear on the computer screen for:

- A. Entering new data
- B. Retrieval of data

A. \$ RUN UPDATE.EXE  
 ENTER THE CATALOG NUMBER OF THE RECORD YOU WISH TO UPDATE FOR EXAMPLE, '0004'  
 '0004'  
 \*\*\*\*\*  
 \* MENU \*  
 \* GENUS-1 STATE-3 COUNTY-5 COLLECTION #-7 \*  
 \* SPECIES-2 DRAINAGE-4 DATE-6 # OF SPECIMENS-8 \*  
 \*\*\*\*\*  
 ENTER THE NUMBER OF THE CHARACTERISTIC YOU WISH TO CHANGE  
 3  
 ENTER THE CORRECTION OR CHANGE YOU WISH TO MAKE- IN SINGLE QUOTES.  
 'VA'  
 FORTRAN STOP  
 \$

B. \$ RUN DELETE.EXE  
 ENTER THE CATALOG NUMBER OF THE RECORD YOU WISH TO DELETE, THE ENTRY SHOULD  
 BE IN SINGLE QUOTES, FOR EXAMPLE '0003'  
 '0060'  
 FORTRAN STOP  
 \$

### Figure 3.

Commands and examples that appear on the computer screen for:

- A. Updating data
- B. Deleting data

```
$ RUN FIND.EXE
ENTER THE CATALOG NUMBER OF THE RECORD YOU ARE INTERESTED IN
'0093'

      SPECIFIC INFORMATION REFERRRING TO RECORD NUMBER 0093
      -----

COLLECTED IN MAIDENS, VA 300 FEET DOWNSTREAM FROM BRIDGE, COLLECTED BY
WOOLCOTT, KAMPS, AND QUISENBERRY
END OF FILE OR NO SUCH FILE EXISTS
FORTRAN STOP
$
```

### Figure 4.

Commands and example for retrieving data from secondary file.



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## Habitat Associations Among Small Mammals in an Oldfield Community on Butt Mountain, Virginia

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### ABSTRACT

Habitat associations of small mammals in a 20-25 year old-field community on Butt Mountain, Virginia were examined by live trapping in the summers of 1978-1980. There were 262 total captures of seven species of small mammals: Blarina brevicauda (53 captures), Clethrionomys gapperi (8), Microtus pennsylvanicus (12), Napaeozapus insignus (69), Peromyscus maniculatus (60), P. leucopus (25) and Zapus hudsonius (35). Six variables describing microhabitat characteristics were measured at each capture site. A discriminant function analysis significantly discriminated among the seven small mammals with respect to the habitat variables. Habitat preferences of small mammals were generally similar to those reported by other authors, except for those normally associated with deciduous forests. Unexpected habitat associations exhibited by Napaeozapus insignus and Clethrionomys gapperi may have been the result of the proximity of forest habitats to this isolated old-field or the successional nature of the habitat or both.

### INTRODUCTION

Previous studies of patterns of habitat use by small mammals (Dueser and Shugart 1978, Kitchings and Levy 1981, Porter and Dueser 1982) have illustrated the usefulness of discriminant function analysis in the characterization of species-specific differences in habitat use among mammals. Dueser and Shugart (1978) found marked differences in habitat utilization among four species of mammals (Blarina brevicauda, Ochrotomys nuttalli, Peromyscus leucopus, Tamias striatus) in an upland forest community in eastern Tennessee. Kitchings and Levy (1981) reported similar results for the same four mammal species in a Tennessee cedar-pine-oak forest. In a barrier island mammal community of six species (Cryptotis parva, Microtus pennsylvanicus, Mus musculus, Oryzomys palustris, P. leucopus, Zapus hudsonius), Porter and Dueser (1982) used discriminant analysis to differentiate among species according to habitat preferences.

The present study investigates habitat relationships among seven species of small mammals short-tailed shrew, (B. brevicauda), deer mouse (P. maniculatus), white-footed mouse (P. leucopus), southern red-backed vole, (Clethrionomys gapperi), meadow vole (M. pennsylvanicus), meadow jumping mouse, (Z. hudsonius) woodland jumping mouse, (Napaeozapus insignus), on Butt Mountain, Virginia. These species were live-trapped during the summers of 1978-1980 in a mountain top field abandoned since the 1950's. The objectives of this research were 1) to characterize

habitat relationships among the seven small mammals, and 2) to compare, whenever possible, the observed habitat preferences with published information on their habitat preference. The results of this study should also provide useful information on the effect of small isolated clearings within a forested area on interspecific interactions.

#### MATERIALS AND METHODS

The study site located on Butt Mountain, Giles County, Virginia (elevation 1250 m), was an old-field community established 20-25 years after a 50 year period of agricultural maintenance. The rectangularly shaped old-field comprised approximately 6 ha and was surrounded by chestnut oak (Quercus prinus) forest. Vegetation in the clearing consisted primarily of grasses, forbs, a mixed assemblage of vines and shrubs with black locust (Robinia pseudoacacia) at the forest margin.

A rectangular shaped 200 m by 50 m trapping grid with one hundred stations, spaced at 10 m intervals was established within the boundaries in 1978 and one hundred Sherman live traps (8 cm x 9 cm x 22 cm) were set one per station. Live trapping was conducted on the grid during the summers of 1978-1980. In 1978 and 1980 trapping was conducted for one week during August. In 1979 the grid was trapped for one week each during June, July and August. A total of 3500 trapnights was recorded over the period of the study. Vegetation variables were measured once during each trapping period. Hence there were a total of 500 possible vectors associated with a capture.

At each trap site, the percent cover of grass, forbs, and shrub vegetation types were measured using the cover density board method (Phillips 1959). In addition, the presence or absence of sapling trees, Rubus spp., and Vaccinium spp. was recorded. During August the field was characterized by an abundance of fruit (blackberry, dewberry, and blueberry) totally absent in the surrounding forest. A discriminant function analysis (SAS Candisc procedure) was performed on the small mammal species using the six vegetation variables. Vegetation variables associated with captures of mammal species were analyzed using canonical variate analysis (SAS Can procedure 1982). Each data point consists of the species captured and the measurements on the six vegetation variables. A total of 262 different mammals were captured and used in the analysis. Only the data from an individuals first capture were used in the subsequent analysis.

#### RESULTS AND DISCUSSION

Seven species of small mammals were captured in the old-field habitat: Blarina brevicauda (53 individuals), Clethrionomys gapperi (8), Microtus pennsylvanicus (12), Napaeozapus insignis (69), Peromyscus leucopus (25), P. maniculatus (60), and Zapus hudsonius (35). A discriminant function analysis using the six habitat variables discriminated significantly (Wilk's  $\lambda = 0.79$ ,  $P = 0.006$ ) among the seven species. The first two canonical variables (CV's) accounted for 45.3% and 25.5%, respectively, of the total discriminating information in the vegetation variables. The first CV was negatively correlated with grass cover and positively correlated with the presence of tree saplings and shrubs (Vaccinium spp. and Rubus spp.) and describes a gradient of increasing woody cover (Table 1). The second CV was negatively correlated with shrub cover and the presence of tree saplings and Vaccinium spp. and positively correlated with grass and forb cover and represents a continuum of increasing herbaceous cover.

Together CV1 and CV2 describe a two-dimensional herbaceous to shrub vegetative continuum which was important in delineating habitat preferences of these small mammals.

Table 1. Linear correlation between the first two canonical variables and the habitat variables.

Variable	CV1	CV2
Grass cover	-0.67	0.68
Forb cover	0.05	0.66
Shrub cover	0.49	-0.47
Tree saplings	0.34	-0.20
<u>Rubus</u> spp.	0.61	0.06
<u>Vaccinium</u> spp.	0.23	-0.22

The mean scores on the first two canonical variables for Blarina brevicauda (Figure 1) indicated that this species tended to occupy sites with greater shrub than herbaceous cover. Kitchings and Levy (1981) found Blarina to be positively associated with logs and stumps and negatively associated with shrubs in a forest community. Blarina may be more abundant in the forest than in open patchy habitats such as this study area or on large area clearcuts and grasslands (Jameson 1949). When it

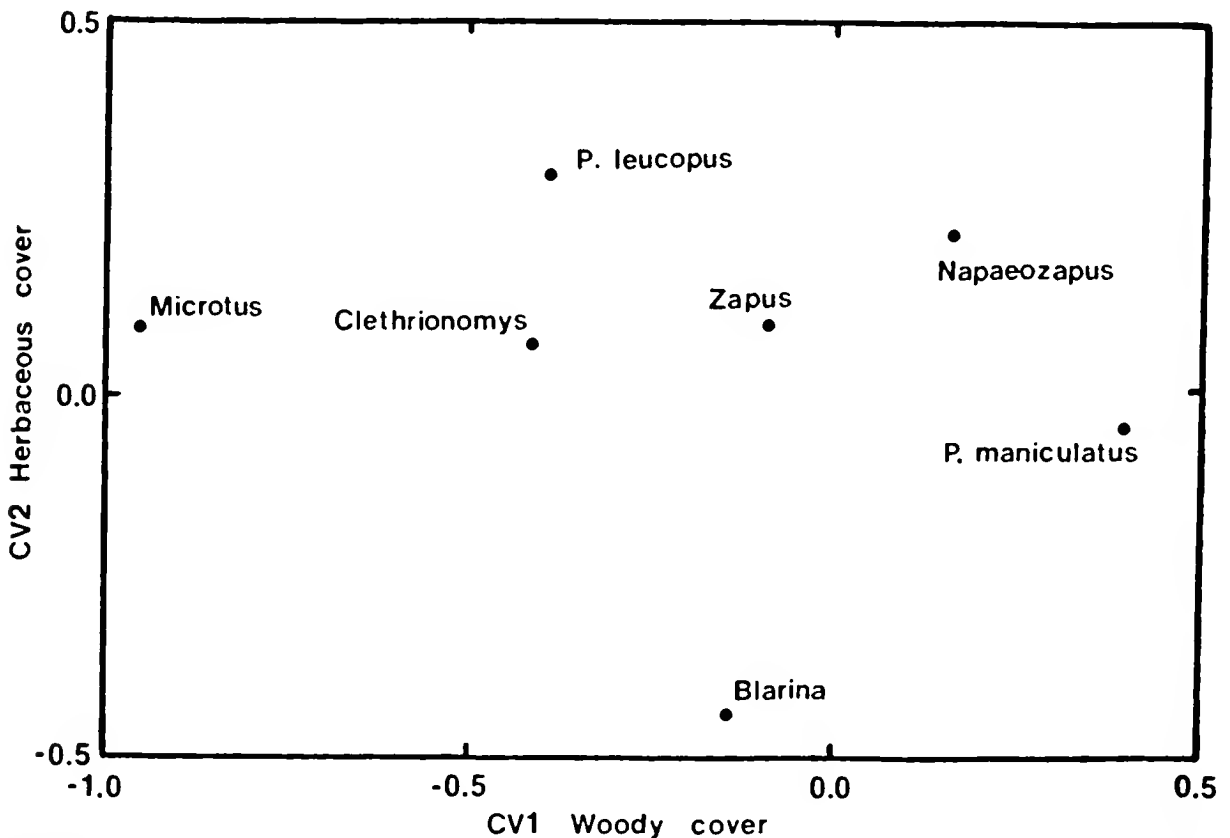


Figure 1.

Mean discriminant scores for the seven small mammal species on the first two canonical axes.

occurs in open habitats, Blarina may prefer sites with greater shrub and tree sapling cover since these represent habitats which share characteristics with woodlands rather than the old-field site which was dominated by herbaceous cover.

Clethrionomys gapperi and Microtus pennsylvanicus were associated with sites with high herbaceous and low shrub cover. Porter and Dueser (1982) also found M. pennsylvanicus to be associated with sites characterized by high grass cover in several barrier island habitats. Microtus spp. are generally associated with grassland habitats (Whitaker 1980) and appear to prefer habitats with lush ground cover (Birney et al. 1976). However, Clethrionomys is usually associated with woodlands (Whitaker 1980) and the few individuals of this species more probably represent transient individuals from the surrounding forest in which Clethrionomys was common and Microtus was rare.

Napaeozapus insignis and Zapus hudsonius tended to occupy intermediate sites with respect to the herbaceous-shrub continuum. Porter and Dueser (1982) also noted that habitat associations for Zapus were intermediate with respect to herbaceous and shrub cover. Zapus is commonly found in fields and brushy habitats while Napaeozapus is considered a woodland species (Whitaker 1980). The occurrence of both Zapus and Napaeozapus in the old-field may be as a result of the transitional character of this habitat or the proximity of oak forest.

The mean canonical means for Peromyscus leucopus and P. maniculatus indicated that P. leucopus occupied sites with high herbaceous cover while P. maniculatus occurred at sites with greater shrub cover. Perhaps Peromyscus leucopus appeared to prefer open, grassy areas in the present study, because P. maniculatus excluded it from shrubby locations. However, in forest habitats, Dueser and Shugart (1978) and Kitchings and Levy (1981) found P. leucopus to occur at sites with low tree density and high density of shrub and herbaceous vegetation. Peromyscus maniculatus was not present in the habitats studied by Dueser and Shugart (1978) or Kitching and Levy (1981).

In most cases, small mammals in the old-field habitat exhibited habitat associations consistent with those described in previous studies. Kitchings and Levy (1981) also found patterns of habitat utilization by the same species of small mammals in different habitats. The proximity of surrounding forest and the disturbed nature of the clearcut habitat may have contributed to the unexpected habitat patterns exhibited by Napaeozapus insignis and Clethrionomys gapperi. If this small field is typical of old-fields in forested areas at high elevations in the Appalachians then such habitats represent useful sites for the study of small mammal interactions. Small mammal diversity is high, yet microhabitat variation may be summarized by a few discriminant gradients.

#### ACKNOWLEDGEMENTS

This paper is dedicated to the memory of Mark S. Maly (N.S.F. Graduate Fellow and V.P.I. & S.U. Cunningham Dissertation Scholar) whose sudden accidental death cut short a very promising career in mammalian ecology. Computing support was provided by the Department of Biology at Virginia Polytechnic Institute and State University. The authors express thanks to D. Pistole, T. Derting and a number of undergraduate research students who aided in various aspects of the field work, and to J. Pagels for a critical review.

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## News & Notes

**Virginia Junior Academy of Science:** The VJAS had a good year for 1985-86. Over 90 clubs and approximately 20 individual members participated. 1218 papers were submitted for reading at the annual meeting held in conjunction with the VAS meeting at James Madison University May 13-16, 1986. A survey indicated that the twelve hundred plus papers were selected from over 7,000 student research projects done at the secondary school level. 654 papers were selected to be read at JMU, in 32 sections dealing with 18 topics. Botany, Consumer Science, Environmental Science, Medical Science, and Psychology-Learning and Perception had three sections each. Four topic areas had two sections each and nine topic areas had one section each. A first, second, third place plus up to three honorable mentions were awarded in each section. The money for these awards was provided by **Philip Morris, USA**.

Several special awards were given. Four students were selected to attend the American Junior Academy of Science meeting on February, 1987 in Chicago. These students are **Andrew B. Moore**, Patrick Henry High School (Hanover Co.); **Rita Gilman**, also a winner of this trip last year and from Patrick Henry High School (Hanover Co.); **Lucy Erin O'Brien**, Langley High School (McLean); and **Rebecca A. Wallace**, Liberty Jr. High School (Hanover Co.).

In just two years the students of **Bethel High School**, Hampton, VA have raised \$10,00.00 to endow a \$1,000.00 scholarship. That scholarship was presented for the first time this year to **Courtney Gay Lyon**, Lee-Davis High School (Hanover Co.). Mr. Tom Bailey, principal of Bethel High School, made the presentation. The VJAS is pleased to have schools like Bethel providing incentives to students of science in Virginia.

The second **Frances and Sydney Lewis Environmental Science Scholarship** was awarded to **Rita Lynn Gilman** of Patrick Henry High School, Hanover County. Rita is a sophomore and her research was on "The Possible Effects of Auto Pollutants on Wood Production of Deciduous and Coniferous Trees." This scholarship, valued at \$10,000.00, is provided by **The Virginia Environmental Endowment, Mr. Gerald P. McCarthy, Executive Director**. The winner of this scholarship last year, **Elizabeth Tongier**, will begin her college career this fall at The College of William and Mary. Elizabeth plans to continue her research at the Virginia Institute of Marine Science.

Two outstanding teachers were recognized. **Ms. M. E. (Meg) Gilman**, Lee-Davis High School (Hanover Co.) was selected for the VAS Outstanding Teacher Award. **Mr. Don Rima**, Bethel High School (Hampton), was selected for the Outstanding Club Sponsor Award.

The E. C. L. Miller Club Award is given to the club which demonstrates outstanding club programs and activities. **Buffalo Gap High School** was this year's winner. Other special award winners include:

Rosco Hughes Award for the best paper in environmental science: "The Possible Effects of Auto Pollutants on Wood Production of Deciduous and

Coniferous Trees" by **Rita Lynn Gilman**, Patrick Henry High School (Hanover Co.)

Botany Section Award for the best work on a botanical subject: "Some Effects of Temperature Extremes on the Early Development in Marsilea Vestita" by **Larry Scott Jackson**, Patrick Henry High School (Hanover Co.)

Neuroscience Award for outstanding papers in the field of neuroscience: "The Effect of Gender on Reaction/Coordination Time" by **Rebecca A. Wallace**, Liberty Jr. High School (Hanover Co.); "A Study of the Effects of Unisom on Ethanol Narcosis Time in Lab Mice" by **Rebecca B. Roden**, Lee-Davis High School (Hanover Co.); "The Effect of the Method of Administration of Scopalamine-Hydrobromide on the Amount of Water Intake of Mice" by **Ashley S. Garber**, Lee-Davis High School (Hanover Co.); "The Long Term Effects of Local and Systemic Anesthetics on White Mice" by **Charles E. Garbett**, Lee-Davis High School (Hanover Co.)

Virginia Veterinary Auxiliary Award for the most significant contribution in the study of domestic animals: "The Effect of Subtherapeutic Levels of Antibiotics on the Resistance of Bacteria in White Mice" by **Christopher Sean Kaloski**, Lee-Davis High School (Hanover Co.)

Mathematics and Computer Science Award for the most significant contribution in the field of mathematics and computer science: "A Computer Simulation of the Early Stages of Visual Information Processing" by **Lawrence A. Halff**, Yorktown High School (Arlington Co.)

Rodney C. Berry Chemistry Award for the most significant contribution in chemistry: "Aromatic Substitution: The Iodination of Anilin" by **Brian Scott Chaples**, Thomas Jefferson High School (Fairfax Co.)

Russell J. Howlett Award for the best research paper of the year: "The Synergistic Effects of Acid Rain, Thermal Pollution, and Phosphate Pollution on Common Shiner Minnows [Notropis cornutus]" by **Courtney G. Lyon**, Lee-Davis High School (Hanover Co.)

**The Richard Gwathmey and Caroline T. Gwathmey Memorial Trust** has awarded the Virginia Academy of Science a \$7,000.00 grant towards the publication of the Proceedings of the Virginia Junior Academy of Science and program for the annual meeting. Because of the tremendous growth of the VJAS during the past several years, the publishing costs have increased considerably. The VJAS is grateful to the Gwathmey Memorial Trust for this needed grant which supports the academy's efforts to publish these two important documents.







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The original and two copies of each manuscript and of all figures therein are required. *Authors should submit names of three potential reviewers.* **All manuscripts must be double-spaced throughout. The title, author's name, affiliation and address should be placed on a covering page. An abstract (on a separate sheet) summarizing the text, particularly the results and conclusions, is required. After revision and final acceptance of an article, the author will be asked to furnish an error-free, camera-ready copy of the manuscript. (Instructions will be provided.)**

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OFFICIAL PUBLICATION OF THE VIRGINIA ACADEMY OF SCIENCE

## Winter 1986

**NECROLOGY** ..... 273



## **Vertebrate Life Histories in Virginia**

Proceedings of a Symposium  
Held at the Annual Meeting of  
**The Virginia Academy of Science**  
Harrisonburg, Virginia, 13-16 May 1986

Arranged by  
**Joseph C. Mitchell**  
University of Richmond

### **Preface to the Symposium**

This symposium grew out of a lunchtime discussion among the vertebrate ecologists at the 1985 Virginia Academy of Science meeting in Williamsburg, VA. Our theme this year was, in a broad sense, studies of the life histories of vertebrates in Virginia. Our objective was to demonstrate the breadth of research on this topic currently going on in Virginia. The symposium contained twelve contributions covering all the vertebrate classes. The first four of the contributed papers summarize studies of small mammal reproduction. These are followed by papers on the diet of an endangered bat, a model for species interactions effects and a summary of life history characteristics of a community of frogs. I hope the success of this symposium will stimulate others to arrange future symposia.

I thank all the speakers, authors and coauthors for participating in the symposium. My organization of it benefited from help from Jack Cranford, Dean Decker, Werner Wieland, and Jim Murray. The following people reviewed manuscripts for me: Jack Cranford, John Pagals, Chris Pague, Bob Rose, Ginny Dalton, Werner Wieland, and Jerry Wolff. Their professional criticisms insured the quality of the papers published in this issue of the Virginia Journal of Science. Sarah Lehman provided considerable secretarial help during the organizational stages. The Virginia Academy of Science, through the efforts of Jim Murray, provided funds to cover the expenses of organizing the symposium and publishing these proceedings.

Joseph C. Mitchell  
30 September 1986

## Life History Strategies of White-Footed Mice (*Peromyscus leucopus*)

Jerry O. Wolff

Biology Department, Villanova University  
Villanova, PA 19085

The behavioral and population ecology of white-footed mice (*Peromyscus leucopus*) were studied at the Mountain Lake Biological Station in southwestern Virginia from 1981 through 1985. The population declined from a high of 38 mice/ha in 1981 to a low of 6 mice/ha in 1983 and increased to 17 mice/ha in 1985. From 1981 through spring 1985 the breeding season was bimodal with peak activity in April through June and September through October with a midsummer breeding lull. Mice bred throughout the 1985-86 winter. Litter size ranged from 3.3 to 3.5 young/litter and females averaged 1.4 litters/year. Sex ratios did not differ from unity. Most spring-born animals reached sexual maturity and bred in fall, except at high densities. The length of residency ranged from 5.7 to 15.6 weeks and was greatest for adults and juvenile females. Juvenile males tended to disperse from their natal sites. Breeding adults were aggressive and territorial only during the high density year; adults were not aggressive toward juveniles. Home ranges were larger among males than females and at low than high densities. Food was not a factor in limiting population numbers. Animals nested alone in trees or underground during summer, and communally underground during winter. Life history strategies of *P. leucopus* are discussed with respect to fluctuations in density and seasonal environments.

### INTRODUCTION

The white-footed mouse (*Peromyscus leucopus noveboracensis*) is widely distributed throughout eastern United States, ranging from Missouri to northern North Carolina and northward to southern Canada (Hamilton and Whitaker, 1979). White-footed mice are found throughout Virginia, but are most common in brushy and woodland habitats. From 1980 through 1985, my students and I have been studying the behavioral ecology of *P. leucopus* in the deciduous forests of the southern Appalachian Mountains. *Peromyscus* generally maintain moderate to low, stable population densities (Terman, 1968; Miller and Getz, 1977; Batzli, 1977), however, in our study area they apparently fluctuate with a 5- to 6-year periodicity (Wolff, 1985a; C. O. Handley, Jr. pers. comm.). These density fluctuations affect reproductive patterns, social behavior, and other life history characteristics. This paper reviews several aspects of *P. leucopus* life history. Methods and results from published works will be summarized briefly with reference made to the appropriate source for details. An extensive literature review on the population ecology and social behavior of *Peromyscus* is available (Wolff, 1985a; Wolff 1986a) and will not be repeated here.

### MATERIALS AND METHODS

Study area. These studies were conducted at the Mountain Lake Biological Station in Giles County, southwestern Virginia (37°10' N. 80°30' W). The station is located at an elevation of



1200 m in the Allegheny Mountains in an oak-maple-hickory forest with scattered rhododendron thickets and an understory of ferns (primarily *Osmunda* spp.) and blueberry (*Vaccinium* spp.). The temperature averages 18°C in summer and -3°C in winter. Winter snowfall (average 175 cm/year) is periodic with intermittent thaws and freezing temperatures occurring from early October until late April. Rainfall averages 140 cm a year. Acorns and other nuts mature in late September, leaf fall occurs in late October, and leaf growth begins in mid-May. A further description of the vegetation and climate is provided by Stephenson (1982). The deer mouse (*Peromyscus maniculatus*) also occurs in this area at a density of one-fourth to one-third that of *P. leucopus* (Wolff, 1985a).

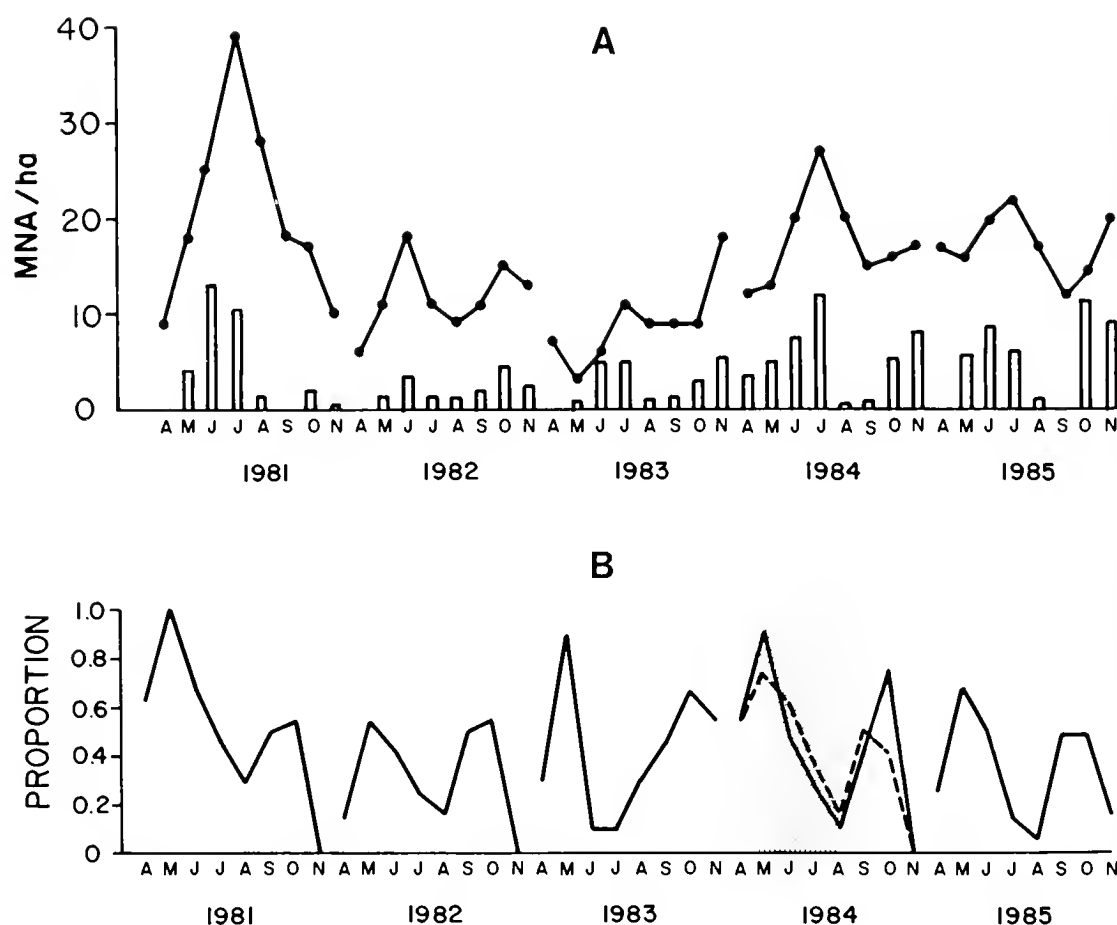
Population data. Animals were live trapped on two 1-ha grids in 1981, four 1-ha grids in 1982, three 1-ha grids in 1983, two 1-ha grids from 1 April 1984 to mid-August 1984, and four 3-ha grids from September 1984 through 25 November 1985. All grids were in similar habitat and within 500 m of each other. Each 1-ha grid consisted of 64 trap stations in an 8 x 8 array with 12.5 m spacing. The 3-ha grids had 196 stations in a 14 x 14 array with 12.5 m spacing. In 1981 and 1982, two large-size Sherman live traps were placed at each station, one on the ground and one between 1 and 2 m in a tree, but with lower densities one ground trap was used per station in 1983 through 1985. Trapping was conducted at 2- to 4-week intervals from April through November each year and at 3- to 4-week intervals during the winter 1984-1985. Traps were baited with solid vegetable shortening and checked daily for 2 or 3 consecutive days. Animals were ear-tagged for permanent identification and species, sex, weight, age, reproductive condition, and trap stations were recorded. Age was recorded as juvenile (gray or gray-brown pelage and  $\leq 15$  g) and adult (sexually maturity, brown pelage and  $\geq 16$  g). Females were recorded as pregnant if they had swollen abdomens, and lactating if they had large nipples. Males were recorded as having scrotal or nonscrotal testes. Animals were snap-trapped from surrounding habitat to determine their actual reproductive condition. Litter size was estimated by counting embryos of snap-trapped animals in 1981 and from field-conceived laboratory-born litters in 1984.

Animals were considered to be residents if they were present for 2 or more weeks. Trappability of animals was 94% (Wolff, 1985a) so minimum number alive (MNA) was used as a close approximation of population density (Hilborn et al. 1976). Analyses were done using SPSS (Nie et al. 1975; Hull and Nie, 1981).

Food Addition. The response of *P. leucopus* to a food supplement has been discussed in two separate studies, Gerzoff (1984) and Wolff (1986b). Only the results of Wolff will be reviewed here. Animals were live-trapped on two 1-ha treatment grids from 1 April to 21 October 1984. Treatment consisted of approximately 200 g of a mixture of oats and sunflower seeds placed in 1-liter, small-necked bottles at each trap station on two grids. The bottles were filled weekly from 1 May to 13 August. The grids, trapping schedule, data collected, and analyses were the same as described above.

Home range. Home ranges were estimated by calculating the minimum area within a convex polygon drawn around the outermost trap locations where each animal was caught (Wolff, 1985b). Home ranges were determined for animals caught between 6 and 12 times over at least a four-week time period on control and food-addition grids, and at high and low densities from 1981 through 1983.

Radionuclide procedure. During the spring and fall breeding seasons of 1984, pregnant females were injected with 1-5 Ci of  $^{59}\text{Fe}$  or  $^{85}\text{Sr}$ , or both radionuclides diluted in 1 ml saline



**Figure 1.**

(a) Minimum number of alive (MNA) of *P. leucopus* from 1981 through 1985. Bars indicate number of new juveniles entering the population each month. (b) Proportion of adult females ( $\geq 18$  g) that were pregnant or lactating each month from 1981 through 1985. Dashed line in 1984 indicates food-addition grids and solid line indicates control grids. Treatment period is shaded.

solution using the procedure of Tamarin et al. (1983). All juveniles that were caught on these grids were scanned on a multichannel analyzer (Wolff and Lundy, 1985; Wolff and Durr, 1986). Each radionuclide produced unique spectral peaks so individuals could be accurately assigned to their mothers and siblings.

**Nest boxes.** Thirty nest boxes were placed on each of two grids in fall 1984 (Wolff and Durr, 1986). Fifteen nest boxes were placed on the ground and 15 were placed 1 to 2 m in trees. Nest boxes were furnished with cotton batting and checked at 3 to 4-week intervals from November 1984 through March 1985.

**Behavior.** Behavior trials between members of the same sex were conducted with resident animals and intruders using the method of Wolff et al. (1983) and Wolff (1985b). All trials were conducted from June through August using adults (scrotal males and sexually mature females that were not obviously pregnant or lactating) and juveniles (that had gray or gray-brown pelage and were not in reproductive condition). Encounters were conducted in a clear, open-bottom, plastic cylinder, 32 cm in diameter and 48 cm high. Trials between adults were conducted in the home range of one of the adults, and trials between adults and juveniles were conducted in the home range of the adult. Each trial lasted 5 min and all agonistic behaviors were recorded (Wolff et al. 1983). The outcome of each trial was classified as resident wins, intruder

Table 1. Sex ratios by litter size determined by embryo counts of snap-trapped animals in 1981, and field-conceived, laboratory-born litters in 1984. Sex ratios are for 1984 only.

Litter size	1981 N	1984 N	Sex ratio M:F	Percent males
1	3	2	1:1	50
2	4	4	3:5	38
3	10	12	20:16	56
4	11	9	19:17	53
5	6	4	2:18	10
6	1	0		
Total	35	31	45:57	44
Litter size 3.5(0.21) 3.3(0.16)				
X (SE)				

wins, draw, or no aggression, based on the number of aggressive and submissive behaviors exhibited by each animal.

## RESULTS

### Population density

A total of 1,868 *P. leucopus* was captured 9,207 times during the 5-year study. The population density (MNA) reached a high of 38 animals/ha in July 1981, declined to a low of less than 6 animals/ha in April 1982 and May 1983, and then increased in 1984 and 1985 (Fig. 1a). In general, the population had two peaks each year with highs in June-July and again in October-November. The mean yearly densities were 22.1, 8.5, 8.3, 17.5, and 17.1 mice/ha from 1981 through 1985.

### Reproduction

Breeding began in late March or early April and continued until late October or mid-November, with peak activity occurring in April through June and again from September to October (Wolff, 1985a; Wolff, 1986b; Fig. 1b). When trapping began in early April, all overwintering males and females were already reproductively active. Adult males had scrotal testes through November, however, testes regressed slightly in July and August. Regression in testes size was associated with a lull in breeding activity among females (Fig. 1b). The interval from first to last birth averaged 206 days [ $\pm$  24.1 SD; Range 178 (1981) to 236 (1984)], except that mice bred throughout the winter of 1985-1986.

A total of 171 pregnancies was recorded for 152 females. Ninety-five percent of the pregnancies occurred in April through June or September through November. Six pregnancies occurred in July and only three pregnancies were recorded in August. This pregnancy pattern was reflected in juvenile recruitment, which was most pronounced in May through July and October through November (Fig. 1a). (See Wolff 1986b and Cranford and Wolff, this issue, for further discussion on seasonal breeding patterns.)

Only 44 females recorded as pregnant remained on a grid for more than six weeks. Of those 44, nine females remained from May through November and had one litter in spring and one in fall, one female had three litters, and two females were pregnant five times each. Six other females had two litters in spring and five females had two litters in fall. The mean

Table 2. Sex ratios of reproductive adults ( $\geq 18$  g) and juveniles ( $\geq 15$  g) in spring and fall from 1981 through 1985.

	Juveniles		Adults	
	Spring M:F	Fall M:F	Spring M:F	Fall M:F
1981	26:25	3:5	34:25	20:11
1982	15:10	24:15	36:23	22:21
1983	18:19	11:20	22:18	16:16
1984	38:42	39:57	48:37	96:85
1985	78:71	45:61	146:130	85:92

number of litters per female that remained on grids for six weeks or longer was 1.4. This may be an underestimate of pregnancy rate because females frequently disperse after weaning a litter, especially if they are pregnant with a second litter.

Mean litter size in 1981 was 3.5 (SE 0.21,  $N=35$ , range 1-6; Wolff, 1985a) and in 1984 it was 3.3 (SE 0.16,  $N=31$ , range 1-5, Table 1). The mean number of young caught per pregnancy was 2.1 for a weaning rate of 64%. In 1985, we identified 37 pups from 11 litters in nest boxes. Twenty-two of these 37 pups were later caught on the grid for a weaning rate of 59%, which is similar to that estimated from live trapping in 1984 and 1985.

#### Sex ratio

Sex ratios did not differ significantly from 1:1 in spring or fall in any year for juveniles or reproductive adults (Table 2). There was no apparent sex-specific differential mortality from one generation to the next for any season or year. Sex ratios did not differ significantly between juveniles in one season and adults in the succeeding breeding season (2x2 contingency tables, all G-statistics N.S.).

The sex ratio of field-conceived laboratory-born litters in spring 1984 favored females (Table 1), but did not differ significantly from 1:1. The female bias was due to a low percentage of females in larger litters. Four litters of five pups had a sex ratio of 2:18. Three of the four litters were all females.

#### Reproductive condition

Reproductive condition of spring-born juveniles that survived to fall breeding seasons were compared with overwintering adults for 1981, 1984, and 1985. Body weights of spring-born males in fall were significantly less than those of overwintered adults during the high density year of 1981 ( $X = 19.2$  and  $21.9$  g, respectively;  $t = 3.91$ ,  $df = 38$ ,  $p < 0.001$ ), but not during 1984 ( $X = 22.2$  and  $23.6$  g, respectively;  $t = 1.38$ ,  $df = 17$ ,  $P > 0.20$ ) or 1985 ( $X = 22.0$  and  $22.0$  for each group ( $t = 0$ ,  $df = 31$ , n.s.)). In 1981, 25% (3 of 12) of spring-born males had scrotal testes during fall and 33% (7 of 21) of spring-born females bred in fall. In 1984, 100% (5 of 5) of spring-born males had large scrotal testes during fall and 88% (14 of 16) of spring-born females bred in fall. In 1985, all 32 (100%) spring-born males had scrotal testes in fall and all 15 (100%) spring-born females bred in fall.

#### Residency

For those animals that remained on a grid for  $\geq$  two weeks, the mean length of residency ranged from 5.7 to 15.6 weeks

Table 3. Mean length of residence (weeks; SE; N) for adults and juveniles from 1981 through 1985.

	Adult Males	Adult Females	Juvenile Males	Juvenile Females
1981	11.8(1.34;34)	13.7(1.88;19)	10.5(3.29;11)	7.8(1.08;24)
1982	6.8(0.92;37)	10.7(1.60;27)	8.7(1.96;15)	15.6(4.42;8)
1983	7.0(0.82;25)	9.8(1.57;9)	4.7(0.49;6)	10.9(1.82;14)
1984	13.6(1.37;41)	12.2(1.35;36)	5.7(0.90;31)	10.6(1.20;27)
1985	9.1(0.73;74)	9.1(0.77;64)	6.7(0.80;37)	9.8(1.03;40)

Table 4. Number (and percent) of animals present on a grid in one breeding season that remained on that same grid until the subsequent breeding season.

	Number Present in Spring 1984	Number that Remained Until Fall 1984	Number Present in Fall 1984	Number that Remained Until Spring 1985
Adult males	20	8 (40)	36	14 (39)
Adult females	29	7 (24)	44	8 (18)
Juvenile males	26	0 (0)	22	0 (0)
Juvenile females	29	7 (24)	34	9 (26)

(Table 3). The general trend was for adults and juvenile females to have longer residencies than juvenile males (see also Table 4).

Using the radionuclide procedure (Wolff and Lundy, 1985; Wolff and Durr, 1986), fifty-five juveniles (26 males and 29 females) were identified as being born on a grid in spring 1984, compared to 56 juveniles (22 males and 34 females) in the fall of 1984. In the subsequent breeding seasons, all juvenile males were gone from the nasal grids, whereas 24% (7 of 29) of the spring-born females, and 26% (9 of 34) of the fall-born females remained (Table 4). The percentages of adults that remained on their same grids over these same time periods were comparable to those of juvenile females. In spring 1984, four of seven adult females moved their home range after weaning their first litter and before giving birth to a second litter. It appears there is a general trend for age- and sex-biased dispersal favoring juvenile males.

#### Aggression

In 1981, 28 of 35 (80%) behavior trials among adult males, and 14 of 20 (70%) trials among adult females resulted in aggression; resident animals won 71% and 86% of these, respectively (Table 5). From 1983 through 1985 aggression occurred in only 15% (15 of 102) of the trials. Both resident and intruders were tolerant of each other and appeared indifferent to each others presence. Intruders frequently avoided residents, but contact that did not elicit aggression

Table 5. Frequency of occurrence of agonistic behaviors and outcomes of behavior trials conducted between resident and intruder adults, and between adults and juveniles.

		Frequency of trials with aggressive behavior		Frequency of trials with nonaggressive contact		Outcome of Trials		
		N				Resident wins	Intruder wins	Draw
Adult-Adult								
1981								
Males	35	0.80	0	20	7	1	7	
Females	20	0.70	0	12	1	1	6	
1983								
Males	19	0	0.68	0	0	0	19	
Females	17	0.05	0.71	1	0	0	16	
1984								
Males	24	0.13	0.86	0	2	1	21	
Females	17	0.24	0.65	2	1	1	13	
1985								
Males	17	0.41	0.65	5	1	1	10	
Females	8	0	0.63	0	0	0	8	
Adult-Juveniles								
1984								
Males	17	0.06	0.82	1	0	0	16	
Females	14	0.07	0.86	1	0	0	13	
1985								
Males	32	0.39	0.65	9	0	0	23	
Females	19	0.11	0.84	2	0	0	17	

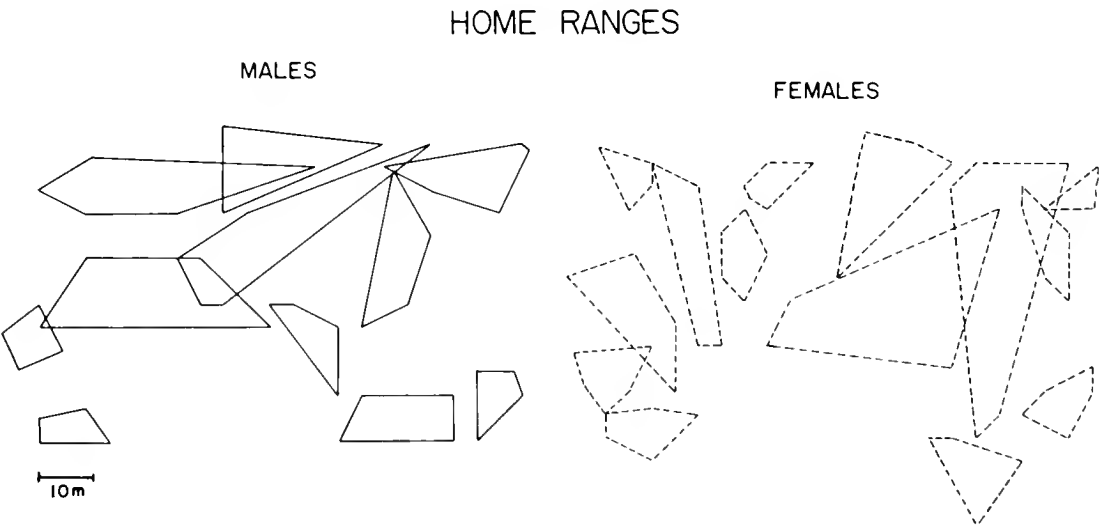


Figure 2. Home ranges of adult males and females on one 3-ha grid during the 1984 breeding season.

Table 6. Mean home range sizes ( $m^2$ ) for *P. leucopus* males and females on control and food-addition grids, and at high and low densities from 1981 through 1983 (adapted from Wolff, 1985b). ( $\pm$  SE, N = number of mice).

	Control Grids	Food-addition Grids	Low density	High density
Males	634( $\pm$ 63,38)	690( $\pm$ 84,17)	717( $\pm$ 94,21)	617( $\pm$ 50,42)
Females	511( $\pm$ 61,22)	377( $\pm$ 62,12)	691( $\pm$ 91,14)*	384( $\pm$ 43,28)*

\*t = 3.48 P < .01

occurred in 63% to 86% of the trials. Contact was always followed by an aggressive response in 1981 (Wolff et al. 1983; Wolff, 1985b).

Aggression occurred in less than 39% of the trials between adults and juveniles in 1984 and 1985 (Table 5). Nonaggressive contact was the most common behavior, occurring in 65% to 86% of the trials. Eighty-five percent of the trials ended in no aggression.

#### Dispersion and spacing

The typical dispersion pattern for adult males and females was exclusive home ranges within each sex and overlapping home ranges between sexes (Figure 2). During the high density year of 1981, home range overlap averaged 37.9% among males and 13.5% among females. At low densities in 1983, home range overlap averaged 7.4% among males and 6.7% among females. The large overlap in 1981 resulted in aggression and intra- and interspecific territoriality (Wolff, 1985b; Wolff et al. 1983; and discussed above). From 1982 through 1985, when densities were below 25 mice/ha, animals were not aggressive and maintained exclusive home ranges by mutual avoidance.

Mean home range size from 1981 through 1983 was 634  $m^2$  for males and 511  $m^2$  for females (Table 6; Wolff, 1985b). Home range sizes on food-addition grids were smaller than on control grids for females, but not for males. Home range sizes were smaller at high than low densities for both males and females.

#### Food addition

The number of females on treatment grids was significantly higher than on control grids from May through mid-June 1984, but declined to the same level as control grids for the next six weeks, even in the presence of supplemental food (Wolff, 1986b). The number of males on treatment grids did not differ significantly from control grids during or after treatment. Gerzoff (1984) found that *P. leucopus* responded slightly to food addition in 1981 but not in 1982. Thus, some factor(s) other than food was limiting the population size during these summers. Pregnancy rate, juvenile recruitment, length of residency, and body weights did not differ between treatment and control grids. Home ranges of females were slightly, but not significantly, smaller on treatment grids than control grids. Males had larger home ranges than females on both treatment and control grids. Even in the presence of a high-quality food supplement, reproductive activity declined during July and August (Fig. 1b). The proportion of females that was pregnant or lactating in May and June or September and October 1984 ranged from 40% to 90%, whereas in July and August it ranged from 0% to 20%. Of the 59 pregnancies, only five of these occurred in July-August (two on control grids and 3 on treatment

grids). Thus 54 of 59 pregnancies occurred during the spring and fall breeding seasons.

#### Nesting behavior

Summer. A total of 79 nest sites was located with radiotelemetry during the summers of 1981 through 1985 (Wolff and Hurlbutt, 1982; Wolff and Durr, 1986). Forty-three nest sites were located in trees and 36 were underground. Underground sites were under logs, piles of debris, in rockpiles, or at the base of stumps. Arboreal sites were located in cavities in dead or live trees, primarily oaks and maples. The mean height of tree nests was 4.3 m (SD = 2.57, range 1-10 m). Trees ranged from 11 to 68 cm in diameter (dbh). Males and females occasionally nested together, but most animals nested alone. Males and females used the same kinds of nest sites. Animals frequently shifted nest sites.

Winter. During winter of 1984-85, 22 underground nest sites were located by tracking animals in the snow (Wolff and Durr, 1986). Thirty-four mice were caught at 12 underground nest sites. No animals were caught at 10 known arboreal sites. The mean group size of animals that entered these burrows was 2.8 (SD = 1.19, range, 1-5). Seventy-four percent (20 of 34) of the animals had been previously caught in the same home range during the fall. Five animals that had moved to a new winter home range moved back to their original fall home range in the spring.

Mother-offspring relationships were verified during the fall breeding season for 12 mothers of 9 juvenile males and 15 juvenile females using the radionuclide technique. During early winter, two groups contained mothers, offspring, and probable fathers (determined by electrophoresis and paternity-exclusion analysis). Most groups contained animals that were not known to be relatives. By spring, all fall-born males were gone from their natal home ranges (Table 4). Five of the 15 fall-born females, however, were breeding within their natal home ranges.

Sixty animals (29 males and 31 females) were located in nest boxes from November 1984 through March 1985 (Wolff and Durr, 1986). Thirty-six of these were found in nest boxes just once. The longest an animal remained in the same nest box was 4 weeks; however, two males returned to the same nest box intermittently for 14 weeks. Only 30% (18 of 60) of the mice were found in the same nest box during a subsequent sampling period (approximately three weeks). Mice did not use nest boxes during the coldest part of winter.

Mean group size in nest boxes was 1.5 (SD = 0.85, range, 1-5, N = 29). Group composition in order of decreasing frequency of occurrence was: single male (12), single female (12), male-female (7), mixed males and females (4), male-male (2), female-female (2).

### DISCUSSION

#### Life History of *Peromyscus leucopus*

A discussion of much of these data is presented elsewhere (Wolff, 1985a,b,c; 1986a,b) and only the seasonal behavioral ecology of *P. leucopus* will be reviewed here. During winter, *P. leucopus* nest communally in groups containing 2 to 5 animals. These communal groups may contain sisters, mothers and daughters, or mothers, daughters, and fathers, but they do not contain sons or brothers. Juvenile males born in fall disperse from their natal home ranges after weaning and prior to the next spring breeding season. In 1984-85, 70% of the adults remained in their fall home range during winter and 28% remained the next spring. Animals occasionally nested in arboreal nest boxes, but most animals nested underground, apparently taking advantage of the thermo-regulatory benefits of snow insulation. No animals



used natural arboreal nest sites during winter.

In late March and early April, males and females became reproductively active and there was a dissociation of the communal groups. Some animals remained in underground nests, but 54% of the summer nests were located in hollow trees (Wolff and Hurlbutt, 1982). Males and females occupied exclusive home ranges with respect to the same sex, but the home range of a male overlapped portions of several female home ranges. A male and female sometimes nested together prior to parturition. Home ranges of males were slightly larger than those of females. At high densities such as in 1981 when all suitable habitat was occupied, males and females were aggressive and actively defended territories (Wolff, 1985b). Territories (defended areas) were evident only during the high density year 1981, whereas there was no aggression between neighbors from 1982 through 1985 so activity areas are referred to as home ranges. Territories were significantly smaller at high densities than home ranges were at low densities. Increased levels of aggression at high densities were correlated with the percent of spatial overlap with same-sex neighbors. At low densities from 1982 to 1985, aggression was reduced, and home ranges were larger and were maintained by mutual avoidance rather than aggression. Thus, aggression was dependent on density and occurred in only one out of five years.

Territory or home range size and location in males was not correlated with food, but apparently resulted from reproductive competition with other males. R. Baccus and J. Wolff (in prep.) found that P. leucopus females mate promiscuously with neighboring males. Consequently, males maintain large home ranges or defend territories which provide access to reproductive females. Home range or territory sizes and location in females, however, were slightly smaller on grids supplied with a food supplement. Females may be defending resources in part, but Wolff (1985c) concluded that females may also be defending their young from infanticide, especially from adult females. In a laboratory study I found that maternal females were more aggressive than nonmaternal females and that in the absence of the dam, intruders would kill pups in the natal nest. I also saw one incident of infanticide in the field when an unmarked immigrant female killed five 8-day-old pups in a nest box while the mother was detained in a live trap (Wolff, 1986c). The intruder subsequently took over the territory. Thus, the function of home ranges or territories differ for males and females, males defend females whereas females defend their young and possibly food resources (Wolff, 1986a).

Females having one or two litters in spring often breed again in fall. Females will sometimes move to a new home range after weaning the first litter and before giving birth to the second litter (Wolff and Lundy, 1985). A considerable amount of dispersal and general movement occur throughout the year among all age and sex groups (Wolff, 1985a) but juvenile males show greater movement than adults or juvenile females (Wolff and Lundy, 1985). The mean length of residence for juvenile males was significantly less than that of juvenile females. Dispersal of juvenile males prevents mother-son and brother-sister matings and thus might function to prevent inbreeding (Wolff and Lundy, 1985). The fact that adult males were not aggressive toward juvenile males suggests that dispersal was "voluntary" and not "forced" by adult aggression as suggested as a mechanism of population regulation in P. maniculatus (Sadleir, 1965; Healey, 1967). Alternatively, juvenile males may disperse to reduce competition with resident males and to increase mating opportunities in new areas. Some daughters disperse, but others inherit their natal home ranges and may become sexually mature and breed in the home ranges of their fathers. Inbreeding between fathers and daughters seems possible, but the

probability of a father occupying the home range of his daughter when she becomes sexually mature is less than 5% (Wolff et al., in prep).

Spring breeding occurred from April through June with juvenile recruitment from May through July. Mean litter size ranged from 3.3 to 3.5; and about 64% of the neonates were caught on the grids. Nestling mortality may account for the other 36%, or alternatively, they may disperse or die before they are caught in traps. Sex ratios within a litter did not differ from 1:1, but larger litters seemed to be female-biased. This female-bias in larger litters would suggest that females are the "weaker" sex and that differential parental investment would favor males (Trivers and Willard, 1973).

Breeding activity declined substantially in July and August and resumed in September and October. The reason for this lull in breeding activity is not known, but it does not seem to be food-related (Wolff, 1986b). The population declined and breeding stopped in July and August even in the presence of a food supplement (Wolff, 1986b; Gerzoff, 1984). Apparently this breeding pattern is ultimately adaptive, but the proximate mechanisms which control this timing have not been determined (See Cranford and Wolff, this issue). Females that have one or two litters in spring may need a physiological recovery period of one or two months before breeding again in September. However, animals in the laboratory will frequently have 5-9 consecutive litters followed by periods of reproductive dormancy (G. Haigh and J. Cranford, pers. comm.). We have also had two females that were pregnant five times each from April through September in the field so apparently some animals do breed throughout the summer.

At high densities in 1981, 25% and 33% of spring-born males and females, respectively, became sexually mature and bred in fall. At lower densities from 1982 through 1985 when vacant habitat apparently was available for colonization by these young animals, between 88% and 100% of spring-born animals bred in the fall of their first year. The interactions among adults at high densities that resulted in aggression and territoriality may also have inhibited growth and sexual maturation of juveniles.

The social behavior of P. leucopus during the fall breeding season was similar to that in the spring. Some spring-born females had one litter in the fall and adult females had one or two litters in the fall. Exclusive home ranges (or territories) were maintained through the fall breeding season until early November. Juvenile recruitment was usually lower in fall than in spring, but did produce a slight population increase. This pattern differs from many species in which the contribution of young females produces greatest densities in late fall; in P. leucopus the greatest densities usually occurred in June or July. By late November aggression decreased and exclusive home ranges were no longer maintained. All animals nested communally in underground nests with the onset of cold weather (see also Madison et al. 1984). Adults and juveniles tended to remain in their same home ranges throughout the winter and during the next spring breeding season. However, during the 1985-86 winter, animals remained reproductive, maintained exclusive home ranges, and did not nest communally. This winter breeding may have been attributed to a large acorn crop in the fall and a relatively mild winter.

The behavioral ecology and social organization of P. leucopus is intrinsically adapted to changes in density and to extrinsic influences of a seasonal and variable environment. These adaptations are predicted by evolutionary theory and are comparable to life history strategies of P. maniculatus (Wolff 1985a,b; Wolff 1986a; Cranford and Wolff, 1986) and animals living in variable environments (Stearns, 1976; Tamarin, 1978; Krebs and Davies, 1984; Ostfeld, 1985; Wolff, 1985d). Continued

long-term studies on P. leucopus and related species will give further incite to the adaptive significance of variation in life history strategies.

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## Factors Influencing Female Reproduction in Two Species of *Peromyscus* in Virginia

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### ABSTRACT

Variation in maternal mass and parity have independent and significant effects upon the litter characteristics of *Peromyscus leucopus noveboracensis* and *P. maniculatus nubiterrae* maintained in the laboratory. In both species, large dams produce more young per litter than small dams. Although the average mass of *P. leucopus* neonates from different sized litters is relatively constant, that of *P. maniculatus* neonates declines with larger litters. Consequently, *P. leucopus* females appear to be better able to meet the energetic and/or physical requirements necessary to support large neonatal masses than *P. maniculatus* females. In both species, litter size and total litter mass are lowest in females that are primiparous or of high parity. These laboratory results suggest that the late summer decline in mean litter size in a field population of *P. l. noveboracensis* was due to the recruitment of relatively small, spring-born primiparous females into the breeding population.

### INTRODUCTION

Laboratory colony records for female *Peromyscus leucopus noveboracensis* and *Peromyscus maniculatus nubiterrae* were examined for patterns of variation among variables directly involved in production. No direct relationship between litter size and neonate mass have been reported for *P. leucopus*, (Millar, 1975; Fleming and Rausher, 1978; Lackey, 1978). In contrast, a negative correlation of litter size with average neonatal mass at birth has been reported for *P. maniculatus* (Myers and Master, 1983). Because maternal mass can directly affect litter size or litter mass, the effect of maternal mass on these variables needs to be assessed.

Variations in litter characteristics (litter size, neonatal mass, and total litter mass) with maternal mass has been reported for *P. l. noveboracensis* and *P. m. nubiterrae*. However, the effect of maternal mass may vary between as well as within species. Among *P. m. maniculatus* and *P. m. bairdii* relationships between maternal mass and reproductive characteristic differ (Millar, 1979; Myers and Master, 1983). For *P. leucopus*, few references describe specific maternal mass effects on litter characteristics. Lackey (1978), however, has shown distinct differences in maternal mass effects between Michigan and Mexican populations.

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Changes in litter size with parity and/or age of adult females have been reported for P. leucopus, P. maniculatus gracilis, P. m. bairdii (Drickamer and Vestal, 1973) P. l. noveboracensis (Fleming and Rauscher, 1978) and P. leucopus (Lackey, 1978). The statistical analyses, however, did not account for potential maternal mass effects. In a study of P. m. bairdii, when maternal mass was included as a covariate, the effect of parity on litter size became nonsignificant whereas female age had only a slight residual effect (Myers and Master, 1983). Consequently, the magnitude of maternal mass effects on litter characteristics of Peromyscus species needs further clarification.

Direct comparisons of reproductive characteristics between field populations from the same locale as the originating animals for laboratory colonies are relatively rare. In this study, over the period in which P. l. noveboracensis was studied in the laboratory, their field source population was also monitored for reproductive activity and seasonal changes in litter size.

The objectives of this research are 1) to relate litter characteristics to female age, parity, and mass in P. l. noveboracensis and P. m. nubiterrae in the laboratory and 2) to compare laboratory data for P. l. noveboracensis with data from its local field population.

#### MATERIALS AND METHODS

The animals used in this study were derived from continuously paired outbred laboratory colonies maintained in the Biology Department of Virginia Polytechnic Institute and State University. The P. l. noveboracensis colony was derived from wild stock captured on Brush Mt. and along Craig Creek, Montgomery Co., 8 km northwest of Blacksburg, Va. The P. m. nubiterrae colony was derived from wild stock captured on Potts Mt., Giles Co., 8 km west of New Castle, Va. Both species were housed in plastic shoebox cages (30 by 20 by 20 cm) with sawdust bedding. Pro lab 3000 rodent chow and water were provided ad libitum. Animal colonies were maintained at  $20\pm 1^{\circ}\text{C}$  and on a LD 16:8 photoperiod. Cages were checked for litters once or twice daily.

Lifetime breeding records maintained for individual females included: female date of birth, dates of litter birth and weaning, and litter sizes at birth and weaning. For subsets of each colony, maternal mass within 24 h of parturition, neonatal mass within 24 h of birth, and pup mass at weaning were recorded. Breeding records from 1983 and 1984 for 85 P. leucopus and 83 P. maniculatus females that each produced at least three litters were used in statistical analyses.

Field data were obtained from a population of P. l. noveboracensis live-trapped from February, 1983 to November, 1984. The trap site was located in a 10 yr old clearcut on Brush Mt., Montgomery Co., 8 km northwest of Blacksburg, Va. Trapping was conducted every 21-28 d (mean=23.8 d) on a 0.91 ha grid, with traps spaced 6 m apart in a 16 by 16 grid. Vegetation included oaks, maples, and pines as overstory, with blueberry, blackberry, greenbrier, grasses and forbs dominating the understory. The data collected at each capture included trap location, animal identification (by ear tag number), pelage type (juvenile, subadult, or adult), total and body length, body mass, and reproductive condition. Females were classified as having a perforate or nonperforate vagina and as either lactating or nonlactating. In addition, all adult females were palpated for embryos to determine potential litter size. Palpation techniques used in the field have been previously verified in the laboratory colonies to have 97% accuracy and 95% from field caught animals.

Data were analyzed using parametric and nonparametric

**Table 1.** Comparisons of reproductive parameters between P. l. noveboracensis and P. m. nubiterrae for litter size, neonatal mass, total litter mass, and maternal mass postpartum. All data are presented as means  $\pm$  1 S.D. Sample sizes are given in parentheses. Statistical differences between the species are indicated by asterisks with (\*)  $p \leq 0.05$ , (\*\*)  $p \leq 0.001$ , and (\*\*\*)  $p \leq 0.0001$ .

	<u>P. leucopus</u>	<u>P</u>	<u>P. maniculatus</u>
Litter size	4.2 $\pm$ 1.4 (455)	*	4.0 $\pm$ 1.6 (490)
Neonatal mass (g)	2.3 $\pm$ 0.4 (105)	***	2.1 $\pm$ 0.3 (110)
Litter mass (g)	9.6 $\pm$ 2.9 (105)	***	7.8 $\pm$ 2.6 (110)
Maternal mass (g)	27.2 $\pm$ 3.3 (100)	***	22.0 $\pm$ 2.6 (114)

**Table 2.** Variation in neonatal mass, total litter mass, and postpartum maternal mass with differences in litter size for P. l. noveboracensis and P. m. nubiterrae. Means are followed by one standard deviation, sample size is given in parentheses. For P. leucopus litter sizes of one too infrequent to include.

Litter Size	Neonatal Mass (g)	Litter Mass (g)	Maternal Mass (g)
<u>P. leucopus</u>			
2	2.3 $\pm$ 0.3 (10)	4.5 $\pm$ 0.6 (10)	26.2 $\pm$ 3.5 (10)
3	2.5 $\pm$ 0.4 (21)	7.4 $\pm$ 1.3 (21)	25.0 $\pm$ 2.0 (20)
4	2.4 $\pm$ 0.4 (32)	9.5 $\pm$ 1.5 (32)	26.8 $\pm$ 3.0 (29)
5	2.2 $\pm$ 0.4 (30)	11.0 $\pm$ 1.8 (30)	28.2 $\pm$ 2.9 (28)
6	2.3 $\pm$ 0.4 (22)	13.6 $\pm$ 2.4 (11)	29.7 $\pm$ 3.1 (11)
<u>P. maniculatus</u>			
1	2.3 $\pm$ 0.4 (6)	2.3 $\pm$ 0.4 (6)	21.5 $\pm$ 3.2 (6)
2	2.4 $\pm$ 0.5 (11)	4.7 $\pm$ 1.0 (11)	20.3 $\pm$ 2.3 (10)
3	2.1 $\pm$ 0.3 (22)	6.4 $\pm$ 0.8 (22)	21.3 $\pm$ 2.0 (22)
4	2.0 $\pm$ 0.3 (36)	8.2 $\pm$ 1.0 (36)	21.9 $\pm$ 2.4 (36)
5	1.9 $\pm$ 0.3 (26)	9.7 $\pm$ 1.5 (26)	22.3 $\pm$ 2.8 (26)
6	1.8 $\pm$ 0.3 (7)	11.1 $\pm$ 1.8 (7)	23.9 $\pm$ 2.5 (9)

statistical tests. All variables measured were normally distributed within each species except parity. When data from all females were combined for each species, regardless of parity, litter size, or age, Pearson's product moment correlation was used to determine the significance of relationships between the measured variables. However, correlations between variables within each litter size, parity, maternal mass, or age group were assessed using Spearman's rank correlation coefficient. This test was used because sample sizes within some parity and litter size groups were small and tended to be nonnormally distributed.

**Table 3.** Effect of parity on litter size, neonatal mass (g), and total litter mass (g) for *P. l. noveboracensis* and *P. m. nubiterrae*. "Unadj" columns are simple means and statistics from analysis of variance. "Adj" columns are means adjusted for maternal mass and statistics from analysis of covariance. Sample sizes are given in parentheses.

	<u>Litter size</u>		<u>Neonatal Mass</u>		<u>Litter Mass</u>	
	Unadj	Adj	Unadj	Adj	Unadj	Adj
<u><i>P. leucopus</i></u>						
1	3.4 (85)	3.5	2.2 (12)	2.3	8.3 (12)	7.8
2	3.9 (67)	4.5	2.5 (28)	2.5	9.8 (28)	10.4
3	4.1 (61)	4.0	2.4 (23)	2.4	9.9 (23)	9.8
4	4.6 (58)	4.3	2.4 (16)	2.3	10.5 (16)	9.9
5-6	4.3 (64)	4.5	2.1 (7)	2.1	8.4 (7)	9.2
7-8	4.5 (41)	4.2	2.1 (5)	2.1	10.7 (5)	8.5
9-10	4.8 (28)	3.4	2.2 (5)	2.2	9.2 (5)	7.8
ANOVA	F = 6.7	1.1	1.8	1.5	1.1	1.2
	p < 0.001	0.4	0.1	0.2	0.4	0.3
	r <sup>2</sup> = 9%		11%		7%	
<u><i>P. maniculatus</i></u>						
1	3.3 (82)	3.8	2.2 (12)	2.1	6.7 (12)	7.9
2	4.1 (72)	4.1	2.2 (28)	2.2	8.6 (28)	8.7
3	4.1 (68)	4.2	2.1 (25)	2.1	8.8 (25)	8.8
4	4.4 (55)	4.3	2.0 (17)	2.1	9.1 (17)	8.8
5-6	4.3 (65)	2.9	2.1 (4)	2.1	4.9 (4)	4.7
7-8	4.4 (43)	3.3	1.9 (13)	1.9	6.5 (13)	6.5
9-10	4.1 (38)	2.9	1.8 (7)	1.9	4.8 (7)	4.0
ANOVA	F = 4.6	2.9	2.2	1.4	6.4	6.7
	p < 0.001	0.01	0.05	0.2	0.001	0.001
	r <sup>2</sup> = 6%		11%		30%	

One-way analysis of variance and covariate analyses were used to determine differences in litter characteristics across parity, litter size, and maternal age groups. All analyses were conducted using SAS statistical programs. Correlations and differences among groups were considered statistically significant at  $p \leq 0.05$ . Field data for seasonal litter analysis were pooled into pre-solstice conceptions (March-July 4) and post-solstice conceptions (July 10-November).

## RESULTS

The 85 *P. l. noveboracensis* dams produced 455 litters. Maternal ages ranged from 65 to 827 d and maternal masses ranged from 20.2 to 34.2 g. The 83 *P. m. nubiterrae* dams produced 490 litters, maternal ages ranged from 59 to 721 d and maternal masses ranged from 16.2 to 28.9 g. Average litter size, neonatal mass, total litter mass, and postpartum mass of dams were all significantly greater in *P. leucopus* than in *P. maniculatus* (Table 1).



### Litter size and mass

P. leucopus. Combining all data for P. leucopus dams as litter size increases average neonatal mass does not change ( $r^2=2\%$ ,  $p<0.12$ ). Therefore litter size and total litter mass are proportional with litter size accounting for 69% of the variation in total litter mass ( $p<0.0001$ , Table 2).

When dams of parities 1-6 are considered as a group, average neonatal mass tends to be negatively correlated with litter size, and variation in litter size account for 4-41% of the variation in neonatal mass. However, only in first litters is this relationship significant (i.e., parity=1;  $r^2=41\%$ ,  $p<0.02$ ).

Total litter mass is significantly and positively correlated with litter size within each parity ( $r^2=41-81\%$ ,  $p<0.0001$ , Table 3). Although there is no clear pattern of increasing or decreasing correlation coefficients, the positive relationship between total litter mass and litter size is strongest at intermediate parities (2-4,  $r^2=72-79\%$ ,  $p<0.0001$ ).

P. maniculatus. Neonatal mass decreases significantly as litter size increases when data for all P. maniculatus females are combined, ( $r^2=15\%$ ,  $p<0.0001$ ). The total litter mass, continues to increase as litter sizes become larger, inspite of the progressively smaller mass of individual neonates. Litter size explains 14% of the variation in neonatal mass and 79% of the variation in total litter mass (all  $p<0.0001$ , Table 2).

Neonatal mass is consistently and negatively correlated with litter size when each parity is considered separately. Litter size explains 10-29% of the variation in neonatal mass. This relationship is significant at the extreme parities of 2 and 7-8 ( $r^2=14-29\%$ ,  $p<0.05$ ), but not at intermediate parities ( $r^2=10-18\%$ ,  $p=0.09-0.68$ ). As expected, total litter mass is significantly and positively correlated with litter size within each parity. All  $r^2$  values are high, ranging from 69-96%.

### Maternal mass and litter characteristics

P. leucopus. Large dams tend to produce more neonates than small dams. Maternal mass accounts for 47% of the variation in litter size, when all parities are pooled, ( $p<0.0001$ ). When each parity is considered independently, the positive correlation between litter size and maternal mass is significant only at parity 3 ( $r^2=52\%$ ,  $p<0.0001$ ).

When litters of all sizes are combined, maternal mass is not significantly correlated with average neonatal mass. Within each litter size, when all parities are combined or are considered independently, there is still no significant relationship between maternal mass and neonatal mass.

Total litter mass, which is proportional to litter size, is strongly and positively correlated with maternal mass. When all parities are combined, maternal mass accounts for 19% of the variation in litter mass ( $p<0.0001$ ). When each parity is considered alone,  $r^2$  values are highest at intermediate parities (parity=3,  $r^2=56\%$ ,  $p<0.0001$ ; parity=4,  $r^2=22\%$ , parity=5-6,  $r^2=61\%$ ,  $p<0.04$ ). At extreme parities,  $r^2$  values are substantially lower ( $r^2=1-4\%$ ), but sample sizes are also small. Within each litter size, maternal mass does not explain a significant percentage of the variation in total litter mass.

P. maniculatus. As in P. leucopus, large dams produce more pups than small dams ( $r^2=10\%$ ,  $p=0.0006$ ). Within each parity this slight positive relationship persists, but is significant only at parities of 2 and 3 ( $r^2=14-16\%$ ,  $p<0.05$ ).

In contrast to P. leucopus, maternal mass of P. maniculatus is negatively correlated with average neonatal mass when all parities are combined ( $r^2=8\%$ ,  $p=0.004$ ). This relationship is not consistent, however, when parities are examined independently. At low parties (1-3) neonatal mass tends to increase with maternal

**Table 4.** Summary of field data for *P. l. noveboracensis* in 1983 and 1984 for the percent of captured females that were pregnant, mean litter size, and total number of embryos palpated. N = number of pregnant females in each sample month.

Month	N		%Females Breeding		Litter Size		Total No. Embryos	
	1983	1984	1983	1984	1983	1984	1983	1984
March	6	4	33	40	3.5	4.0	21	16
April	8	6	80	75	3.8	3.7	30	22
May	5	7	83	88	3.6	3.0	18	25
June	8	5	100	83	3.5	2.9	28	19
July	7	11	37	44	3.4	3.3	23	36
August	6	6	67	40	2.9	3.8	17	16
September	9	8	82	67	3.3	3.4	30	27
October	6	7	86	88	2.8	3.0	17	21
November	3	5	36	36	2.3	2.6	7	13

mass, whereas at higher parities the opposite pattern occurs. Within each litter size, large dams produced smaller neonates, but the relationships is not statistically significant.

In contrast to *P. leucopus*, there is no significant correlation between total litter mass and maternal mass when all parities are combined ( $r^2=2\%$ ,  $p=0.18$ ). Within each parity, total litter mass is consistently and positively correlated with maternal mass. This relationship is statistically significant at parities of 1 and 2 ( $r^2=58\%$  and  $r^2=21\%$ , respectively,  $p<0.02$ ). Within each litter size, total litter mass tends to decline with increasing maternal mass, but not significantly.

#### Parity and Age of Dams

*P. leucopus*. Females continue to gain mass slowly throughout their lives. To separate the effects of maternal mass from that of parity and age, analyses were conducted with and without maternal mass as a covariate. Parity has a significant effect on litter size, primarily due to the occurrence of low litter sizes at parities of 1 and 2 (one-way ANOVA,  $p<0.0001$ ). This effect disappears when maternal mass is included as a covariate (Table 3). Consequently, the production of small litters at low parities is attributable to the relatively small size of dams at these parities. Parity has no significant effect on neonatal mass or total litter mass with or without maternal mass as a covariate (one-way ANOVA,  $p<0.10$ ). Similar analyses were performed on litters classified by female age, using animals of all parities grouped by 50 d intervals. Litter size, neonatal mass, and total litter mass are not related to maternal age with or without maternal mass as a covariate.

*P. maniculatus*. Without considering maternal mass, parity has a significant effect on litter size and total litter mass, and neonatal mass (one-way ANOVA,  $p<0.0002$ ,  $p<0.001$  and  $P\leq 0.05$  respectively), (Table 3). Litter size and total litter mass are highest at intermediate parities of 2-4. The effect of parity on litter size and total mass, but not that on neonatal mass, persists after maternal mass is included as a covariate in the

analyses. These results differ markedly from those for P. leucopus where parity has no effect on litter characteristics after accounting for variation in maternal mass. When litter size is used as the covariate, the significant relationships between parity and neonatal mass or total litter mass remain. As in P. leucopus, maternal age does not influence litter characteristics with or without maternal mass as a covariate.

In summary, large litter sizes with correspondingly large total masses occur at intermediate parities in P. maniculatus and are not attributable to differences in maternal masses or age. However, the larger size of individual neonates at intermediate parities is possibly attributable to the relatively large size of dams.

#### Field P. leucopus

The analysis of field litter sizes shows no significant differences between years, with litter sizes averaging  $3.3 \pm 0.5$  in 1984 and  $3.3 \pm 0.6$  in 1983 ( $X \pm S.D.$ , Table 4). Likewise, litter sizes did not differ between years or any month. After pooling the data for the two years, litter size was found to be significantly lower in November than in any other month (one-way ANOVA,  $p < 0.01$ ). Comparison of pre- and post-summer solstice months yielded a significant difference in the mean litter size of these two periods. Pre-solstice litter sizes averaged  $3.6 \pm 0.2$  while post-solstice litter sizes were smaller, averaging  $3.0 \pm 0.5$  ( $t=2.96$ ,  $p=0.01$ ). The total number of females breeding varied across months but not between years. Significantly fewer breeding females occurred in March and November samples than during any other month.

### DISCUSSION

Variation in maternal mass contributes significantly towards explaining variation in some litter characteristics of P. l. noveboracensis and P. m. nubiterrae. However, the effects of maternal mass are not always comparable in both species. Although heavier dams consistently produce more pups than lighter dams, the effect of maternal mass is stronger in P. leucopus than in P. maniculatus. Heavier P. leucopus dams produce litters of greater total mass than lighter dams; however, litter mass is not influenced by maternal mass in P. maniculatus. The relationship between maternal mass and neonatal mass also differed between species. In P. maniculatus, neonatal mass declines as maternal mass increases, contrasting with the relatively constant masses of P. leucopus neonates regardless of maternal mass. These results agree well with those of similar studies of P. l. noveboracensis (Lackey, 1978) and P. m. bairdii (Myers and Master, 1983). However, in a field study of P. m. maniculatus litter size did not vary predictably with maternal mass (Millar, 1979).

Differences in litter characteristics of the species' reported here are partially due to the relationships between litter size and neonatal mass. In this and other studies of P. l. noveboracensis (Fleming and Rauscher, 1978; Lackey, 1978; Millar, 1975), average neonatal mass remains relatively constant and, therefore, total litter mass increases as litter size increases. On the other hand, in P. maniculatus, as litter size larger average neonatal mass decreases. Decreasing neonatal masses with increased litter size have also been reported for P. m. bairdii (Myers and Master, 1983) and for a Michigan population of P. leucopus (Lackey, 1978). These results show that as litter size increases with maternal mass the corresponding increase in litter mass is relatively less in P. maniculatus than in P. leucopus. This suggests that the relatively small body mass of P.

maniculatus females limits 1) energy conversion into fetal tissue and/or 2) the mechanical ability of dams to support a large total mass and/or 3) the physical space necessary for growth of large offspring in utero. In contrast, by virtue of their relatively larger body mass, P. leucopus appear better able to energetically, physiologically, and/or mechanically support increased neonatal mass. Reproductive effort, as reflected by the total neonatal mass a female supports through gestation, may therefore be greater in P. l. noveboracensis than in P. m. nubiterrae.

Changes in litter size with parity have been reported for Peromyscus (Drickamer and Vestal, 1973; Fleming and Rasucher, 1978; Lackey, 1978); however, the analyses did not consider the confounding effects of variation in maternal mass or age. Parity has no significant influence on litter characteristics of P. l. noveboracensis once it is separated from the effect of increasing maternal mass or age. Small litter sizes at parities 1 and 2 are largely due to the low masses of females at these parities. In P. m. nubiterrae, however, the occurrence of small litter sizes and low litter masses at extreme parities is largely independent of maternal mass or age. This contrasts with the findings of Myers and Master (1983) for P. m. bairdii, in which parity had a significant effect on neonatal mass, independent of maternal mass, but no independent effect on litter size or litter mass. The production of small litters by primiparous P. m. nubiterrae may be due to their lack of reproductive experience and relative inefficiency of obtaining and converting food-energy into fetal tissue. The production of small litters at high parities may indicate reproductive senescence, with females producing as large a litter as they are capable of supporting throughout the energetically intense phase of lactation.

Variation in parity and maternal mass is likely to influence litter size in field populations. Breeding activity in P. l. noveboracensis on Brush Mt. was bimodal, peaking in April-June and September-October when over 50% of the females were pregnant. Mean litter sizes, however, were significantly smaller in the fall than in the spring. This reduction in litter size may result from marked changes in the age structure of the breeding population. In spring, the breeding female population is comprised of mature primiparous and multiparous females that were born the previous year. Young born in the spring of the current year enter the breeding population during late summer or fall. As has been reported by Wolff (1985), these spring-born females can comprise from 33-100% of the breeding population in the fall, Millar (1979) has also shown that spring-born females in populations in Canada are of relatively low body mass during the fall breeding season. From our laboratory analyses, females of small mass and low parity tend to produce relatively small litter sizes. Consequently, as age structure, changes within a breeding population, shifts in litter size are to be expected. As small primiparous females enter a breeding population containing relatively larger multiparous females, average litter size of that population should become smaller. This prediction, based upon our laboratory data, agrees well with observed shifts in litter size between the pre- and post-solstice summer months.

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## Reproductive Strategies of Meadow Voles, Hispid Cotton Rats, and Eastern Harvest Mice in Virginia

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### ABSTRACT

Patterns of reproduction in small mammals in Virginia were examined by autopsying samples of meadow voles (Microtus pennsylvanicus) collected for 23 months near Charlottesville, of hispid cotton rats (Sigmodon hispidus) collected for 14 months in Portsmouth, and by evaluating live-caught eastern harvest mice (Reithrodontomys humulis) trapped for 15 months in Suffolk and for 12 months in Chesapeake. The meadow vole, a microtine rodent with a north temperate and sub-arctic distribution throughout North America, suspended breeding during the winter of peak density but not of declining density. High metabolic rates and other adaptations for winter seem to permit frequent production of young then. However, both Sigmodon and Reithrodontomys are subtropical species, and in Virginia are living at and near the northern limits of their distributions, respectively. Sigmodon suspends breeding in mid-autumn and resumes reproduction in late spring in eastern Virginia. The breeding season is slightly longer in Reithrodontomys. Low metabolic rates, lack of development of adaptive behaviors, and other features seem to preclude winter reproduction in these species with evolutionary histories in the tropics.

### INTRODUCTION

The ability of a species of mammal to persist at any geographic location depends on its ability to maintain a favorable annual energy budget there. Such an energy budget is balanced when the costs of growth, repair, maintenance, and reproduction are met with adequate energy in the form of food or stored fat. Some species accommodate seasons of food shortages (usually winter) by storing foods (e.g., tree squirrels), by hibernating or slumbering (e.g., ground squirrels or bears), by migrating (e.g., bats), or by a combination of these strategies. For example, many temperate bats migrate and then hibernate.

However, because of their body sizes, food requirements, or evolutionary histories, many small mammals cannot store food, migrate, or hibernate. Such species must continue to forage and consume, usually for longer periods and on lower quality foods, during the winter months. Mammals of small size have additional problems in the winter months in part because: 1) as with all mammals, heat loss to the environment in the wintertime is greater than in the summer months, 2) their small mass means that they have relatively high metabolic rates (Kleiber, 1961) and proportionately larger surface areas across which to lose heat than larger species, and 3) their small size prevents a large accumulation of stored fat or of thick insulative fur, so that they cannot reduce thermal conductance to the extent that large mammals can. Therefore, small mammals that have to confront winter "head on" must consume much food per gram of body weight

just for maintenance energy to sustain themselves. Therefore, it is not surprising that body growth, accumulation of body fat, and reproduction frequently are suspended during the winter months in these species.

Non-hibernating small mammals have the additional problem that they have short average lifespans, usually measured in weeks or months at the longest. (By contrast, hibernating small mammals such as bats and meadow jumping mice, Zapus sp., have lifespans measured in years.) Thus, the average individual cannot defer reproduction until a later time when the season might be more favorable or when larger body size would increase the chances of survival for both parent and offspring. The small mammal must squeeze reproduction into a short life even if it might mean breeding at less than the optimal time. The important point is that frequently a small mammal cannot (or seems not to) wait until favorable conditions of weather and food are available, but instead breeds when it is possible to do so. Larger mammals are more prudent and have breeding seasons that avoid or minimize energy demands for production (pregnancy and lactation) during the winter season.

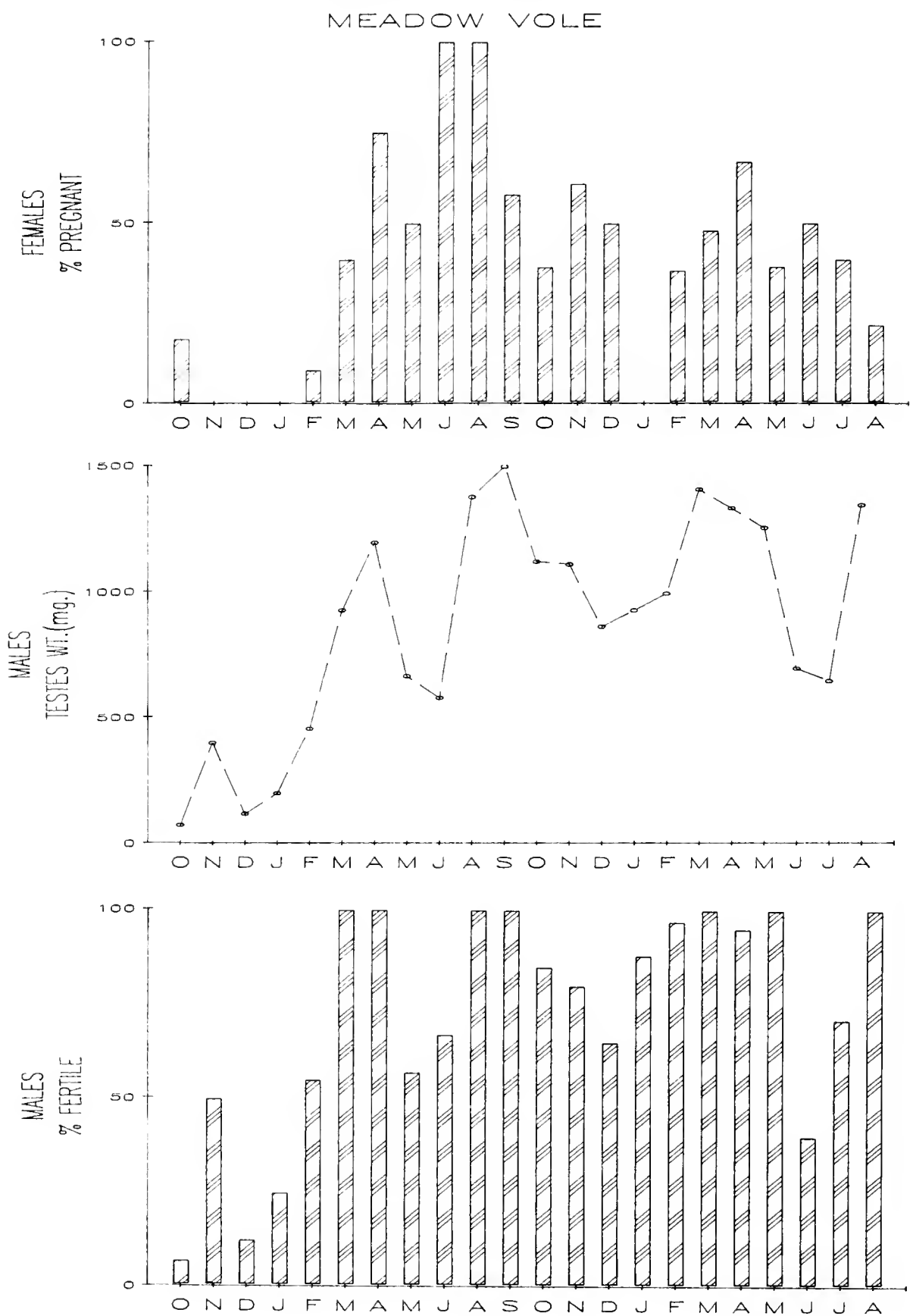
The purpose of this paper is to evaluate the patterns of reproduction in three species of non-hibernating small mammals in Virginia, and to try to understand these patterns in the context of metabolic rates, reproductive potentials, life spans, and other attributes of the species. The three species are Microtus pennsylvanicus, the meadow vole, Sigmodon hispidus, the hispid cotton rat, and Reithrodontomys humulis, the eastern harvest mouse.

#### MATERIALS AND METHODS

Reproduction can be studied either by the external assessment of reproductive features of live-caught males and females that are released for recapture and observation in subsequent weeks or by autopsying dead animals. Each method has advantages and shortcomings. Using live animals, it is difficult to determine when the breeding season starts, because it may take weeks before the first heavily pregnant females are detected. Furthermore, the useful female external features (nipple size, opening of the pubic symphysis, and condition of the vagina), although they can indicate when breeding season is in progress, provide no information on litter size, the past reproductive history of the female, age at first reproduction, or the level of prenatal mortality in the population. The criterion for male reproductive readiness, descended testes, also is not particularly accurate as a predictor of whether there are sperm in the cauda epididymis, the real indicator of fertility in the male. A primary advantage of assessing reproduction in live-trapped mammals is that it is possible to see repeated reproduction in individuals caught throughout the breeding season.

These deficiencies are overcome using autopsied animals, but of course there is no dynamic component in animals evaluated only once. Samples must be collected every 2-4 weeks in order to determine the timing of the breeding season, and sample sizes must be sufficiently large to reduce the chances of sampling error in determining the estimates of reproduction. An additional benefit of the autopsy method is that the weight, length, body fat, size of reproductive organs, and other variables can be recorded and evaluated.

Using live traps, I collected monthly samples of meadow voles (about 15 of each sex) from October 1974 through August 1976 from old fields near Charlottesville. Hispid cotton rats were studied in the same way, using monthly samples collected in an old field in Portsmouth from 1983-1984. Only potentially mature animals were used, i.e., juveniles and small subadults



**Figure 1.** Reproduction in adult meadow voles from Charlottesville. Peak density occurred in October-December 1974. Blanks represent 0%; June 1975 sample missing. Females percent pregnant is based on approximately 15 females/month, except July-August 1975 when samples were less than 5. Male percent fertile is based on percentage of approximately 15 adult-sized males having convoluted cauda epididymides, the measure of the presence of sperm.



## HISPID COTTON RAT

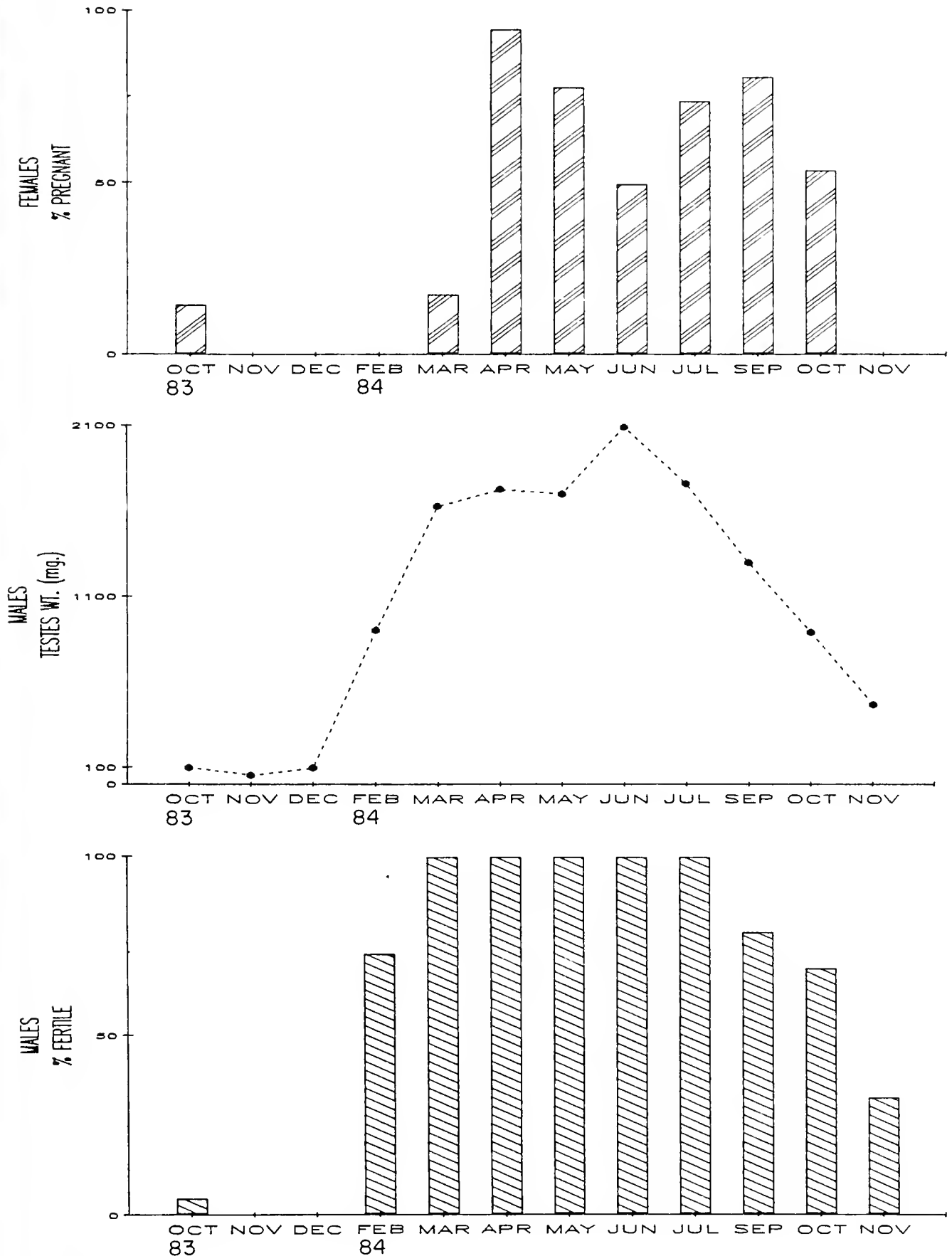


Figure 2.

Reproduction in adult hispid cotton rats from Portsmouth. Blanks represent 0%; no sample in June 1984. Females percent pregnant is based on approximately 15 females/month; male percent fertile is based on approximately 15 males examined for convoluted cauda epididymides, the measure of the presence of sperm.

were released. Reproduction in eastern harvest mice was determined from live animals trapped at two-week intervals during a 15-month study conducted in the Dismal Swamp in Suffolk (Stankavich, 1984) and a 12-month study conducted in Chesapeake (Chandler, 1984).

The techniques used and the variables examined for the autopsied animals are given in Rose and Gaines (1978). In brief, after the standard field measurements were taken, each female was examined for evidence of current or recent reproduction, using embryo and corpora lutea counts as well as the number of placental scars and corpora albicantia. Each male was examined for the presence of convolutions in the cauda epididymis, which indicates that sperm were present and that the animal was fertile.

## RESULTS

### Meadow voles

Embryo counts are the most valid and reliable estimators of breeding level in a population, because they can indicate both the proportion of mature females that are pregnant as well as the litter sizes, which often change throughout the breeding season. Early in the study, when the population was near peak density and early in the decline phase (Dueser et al., 1981), the proportion of pregnant females was low (18% in October, 0.0% in December and January, and 9.5% in February, 1975). Thereafter (Figure 1), the population bred at moderately high levels, with monthly pregnancy rates varying between about 40 and 75%, except for July and August 1975 in which all females from the small samples were pregnant. In the second winter, only in January were no pregnancies detected, in contrast to a much longer period of reproductive cessation during the first winter. Thus, although other variables may have contributed to this pattern, females may have shown an effect of density (Krebs and Myers, 1974) by not breeding during the period of peak density and early in the population decline. However, they did breed at high levels during the long period of population decline that followed.

Males showed similar patterns, with lowest fertility rates and lowest testes weights during the early months of the study. Looped cauda epididymides and low testes weights usually are associated features in nonfertile males. Males showed little evidence, based either on fertility rates or testes weights, of reducing the intensity of reproduction during the second winter, but they did show reduced levels of breeding during both summers (Figure 1). In 1975, male indices dropped sharply in the May and July samples (there was no June sample), and this same pattern was repeated in June and July 1976 (Figure 1). Thus, adult-sized males had low levels of reproduction during the period of peak population density but, except for lower levels during the summer months, thereafter maintained 85-100% monthly fertility.

### Sigmodon hispidus

Although the period of study was shorter than for meadow voles, female cotton rats showed a pronounced shutdown of breeding in the November through February period (no January sample in 1984). There were no pregnancies recorded during this period, and low pregnancy rates were recorded in the border months of October and March (Figure 2). Thus, based on pregnancy rates, the hispid cotton rat was more predictable in its seasonal breeding than the meadow vole.

Using percent fertile, males showed a similar pattern (Figure 2). However, males had a longer period of reproductive competency, appearing to start the breeding season one month earlier than females and ending it later in the autumn. The pattern of testes weights closely paralleled the more reliable indicator of breeding in males, the fertility percentage based on

Table 1. Reproductive indices of male and female eastern harvest mice in the Dismal Swamp, Suffolk (Stankavich, 1984). Winter is defined as November-February, summer as the remaining months. Sample sizes are given in parentheses.

	REITHRODONTOMYS HUMULIS		
	winter 1980-1981	summer 1981	winter 1981-1982
Testes			
scrotal	0.00 (3)	0.93 (14)	0.24 (17)
Nipples medium			
to large	0.33 (6)	0.86 (21)	0.22 (14)
Obvious			
pregnancy	0.00 (6)	0.29 (21)	0.00 (14)

convolutions in the cauda epididymis. The regression of testes is more complete in cotton rats than in meadow voles, especially considering that adult cotton rats outweigh meadow voles by 2-3 times.

#### Eastern harvest mouse

The eastern harvest mouse, with adults weighing less than 10 g, is much smaller than the other two species. Thus, this species probably has much less absolute fat reserve and little potential to reduce thermal conductance by the production of thick, long fur or to deal effectively with the surface/volume ratio problem. Harvest mice were studied using mark-and-recapture methods rather than by autopsying animals, as with meadow voles and cotton rats. Harvest mouse densities were lower and females tended to disappear from the study grids when young were about to be born; both features also contributed to the difficulty of assessing reproduction in harvest mice.

In the 15-month study conducted in the Dismal Swamp (Stankavich, 1984), there was a clear reduction in the indices of breeding activity during the winter months (Table 1). In her study, where winter was defined as the November-February period, the first winter did not include November because the study began in December. This factor might have contributed to the differences between the winters. In Chandler's (1984) study, conducted from March 1983-February 1984, the period of greatest reproduction occurred during the autumn, with a smaller peak in spring. There was a pronounced decrease in breeding in the summer (no pregnant females were observed in June or July), but in the August-November period, 82% of females were either pregnant or lactating. Juveniles entered the trappable population primarily in October and November, but were rare or absent at other times. One strange feature of Chandler's (1984) study, conducted in an upland field dominated by dog fennel and asters, was that females tended to disappear from the study grids when heavily pregnant; only two (of 35) females ever were caught after being recorded as pregnant. This suggested to us that pregnant females might move to new locations for the birth of litters. Juvenile mice, distinguished by their gray pelage, were captured consistently from July through December, and one was captured in May, the month when females were first considered to show evidence of reproduction. Overall, harvest mice were judged to have little breeding in midsummer and midwinter, limited breeding in the spring, and highest breeding levels during autumn.

#### DISCUSSION

Of the three genera, reproduction has been studied most extensively among voles (Microtus) (Keller, 1985). As microtine

rodents, voles have been much studied in the population sense within the past five decades because of their unusual fluctuations of numbers, usually termed population cycles, in which high densities often occur at 2-5 year intervals (Krebs and Myers 1974). Vole reproduction has been studied in part to learn whether changes in level or intensity of breeding might cause population cycles. In brief, changes in reproduction do not cause population cycles but there are some density effects, such as breeding in the winter before the attainment of peak density and halted reproduction during the period of peak numbers.

Because the vole populations were at or near peak density when I began in October 1974 (approximately 300 voles/ha), I have no information about extended breeding in the winter before the attainment of the population peak. However, there was a clear shutdown of reproduction in the autumn and winter of peak density, based on no juveniles, low testes weights, and looped cauda epididymides in adult-sized males, and no pregnancies. Thus, reproduction in the Virginia populations showed this density effect (Figure 1). The level of breeding during the second winter was much greater, with pregnant females occurring in every month except January, and male indices scarcely lower than autumn or spring values.

It should be emphasized that microtine rodents are north temperate to arctic in distribution; M. pennsylvanicus populations extend southward from central Alaska, throughout much of Canada, across the northern two tiers of states in the U.S., and with populations extending south to northern Georgia in the Appalachian Mountains. Thus, the Virginia populations are located near the southern limit of distribution of this widespread species. The winters in Virginia are mild compared with what populations in central Canada and Alaska, or even in the northern states, must tolerate.

One adaptation of voles for dealing with boreal winters is to reduce thermal conductance from the body surface by having dense insulative fur and small ears and tails. Voles in some geographic populations may conserve energy in the winter by suspending or reducing body growth in young animals, by weight loss in adults, and by increasing metabolic rate over warm-season levels (Pistole and Cranford, 1982; Petterborg, 1978). Another mechanism to conserve heat is through the formation of clusters of communally nesting individuals of different ages and sexes (Madison, 1984; Wolff, 1985). Perhaps most important is their efficiency at heat production; voles have much higher metabolic rates than would be expected based on their body sizes (McNab, 1980:Fig 3 on page 110). Voles are among a small group of mammals, including other microtine rodents, weasels, rabbits, and shrews, that have high metabolic rates.

Because of high metabolic rates, these animals are predisposed to having high rates of reproduction, in part because of the efficiency of conversion (McNab, 1980). Progeny have rapid embryonic and postnatal growth rates and can reach reproductive maturity at low weights and at early ages. Large litters are born after 21-day gestation periods, and with postpartum mating being frequent during the breeding season, litters are born at 21-23 day intervals. The reproductive potential of voles is probably greater than for any other group of mammals (Keller, 1985).

With the capacity to maintain a favorable energy (heat) balance because of their high metabolic rates and other adaptations, it is relatively easy for voles to deal with the mild winters of Virginia. This statement is supported by the observation that meadow voles from Charlottesville had positive and substantial growth rates during the winter months (Rose, unpublished), compared to negative growth rates from populations studied at more northerly locations. The most dramatic example

of winter body weight dynamics is Iverson and Turner's (1974) study of meadow voles from Pinawa, Manitoba, where adults lost as much as half of their body weight during the winter months. Most of this loss is in water and muscle mass, for voles have little fat reserves during any season. Virginia voles, then, are capable of production in the form of growth and of fat deposition during the winter months; therefore, it is not surprising that production of young also can occur in winter.

In a study conducted during the winter of 1981-1982 in Chesapeake, Virginia, Rose, Everton, and Glass (In Press) learned that meadow voles also breed during the winter months in eastern Virginia. Autopsies of adult voles collected from Chesapeake and Fisherman Island in late December and early January revealed that 13% of females were pregnant and one-third of males were fertile. In the first week of February (which is probably the "dead of winter" in the Hampton Roads area), 15% of females were pregnant and 38% of males were judged to be fertile. Samples of hispid cotton rats collected in the same fields in Chesapeake showed no evidence of pregnancy or of fertility among males.

In contrast to the meadow vole, the hispid cotton rat is a southwestern U.S. and Mexican species that has greatly expanded its range during historic times. The first specimens in Virginia were caught in 1940 (Patton, 1941), and similar northward movements into the central states also have been documented (Genoways and Schlitter, 1967). At present, central Virginia is the northernmost location of record for the hispid cotton rat on the East Coast (Pagels, 1977). Thus, in Virginia, the cotton rat is living at the northern limit of its distribution. What are mild winters to meadow voles are extreme, cold winters to cotton rats, based on their distributions in North America.

The pattern of reproduction in the Virginia population is remarkably similar to that of a Kansas population of cotton rats (McClenaghan and Gaines, 1978). They found no pregnant females in the November-March period, about 30% pregnant in April, and 40-80% pregnant in the remaining months of their year-long study. Males were not fertile in December-February, and less than 30% were fertile in the months of November, March, and April. Testes weights showed the same pattern of lowest values in the October-March period. Because Kansas and Virginia are marginal locations, it is unclear whether the pattern of no midwinter breeding is typical of the species or whether this cessation represents an adaptation for survival in these northern locations. The definitive studies of reproduction in a Texas or Mexico (i.e., in a central) population remain to be conducted.

Randolph et al. (1975), who investigated the energy costs of reproduction in laboratory populations of S. hispidus, found that ingestion of food was increased by 25% during pregnancy and by 66% during lactation. They also learned that two-thirds of the energy accumulated by a pregnant rat was not converted into neonates, but instead was stored and later mobilized during lactation, when the precocial young grow faster than maternal assimilation alone can support. These results conform to the observation that the cotton rats in my study showed lowest levels of fat during the months of reproduction, and were most obese during midwinter. Tropical and arid grassland-adapted species, such as Sigmodon, usually have low metabolic rates as a means to reduce heat production and to minimize water demand for evaporative cooling (McNab, 1980). Cotton rats do have lower metabolic rates than would be expected based on their body weights, i.e., based on the Kleiber (1961) curve. This predisposes S. hispidus in Virginia, the northern limit of its distribution in the east, to suspend both somatic and embryonic production during the winter months.

Comparable energetic studies have not been conducted on Microtus pennsylvanicus, nor any other American Microtus, but Migula (1969), studying M. arvalis in Poland, learned that

reproduction increases the energy requirements of females by an average of 82.5%, 32% for pregnancy and 133% for lactation. These values will be even higher for females that are simultaneously pregnant and lactating. Voles are able to sustain these energy costs because of extremely high energy conversion efficiencies, which Migula (1969) measured to be 87.7%. It is likely that M. pennsylvanicus has similar energy values for reproduction.

Reithrodontomys is another tropical or sub-tropical genus with some (5) species in the U.S., but the majority of species occur in Mexico and Central America. Thus, the genus is similar to Sigmodon in showing tropical affinities rather than boreal affinities, as in Microtus. Only R. megalotis, the western harvest mouse, extends northward past the Canadian border; the other harvest mice are more limited in their northward distributions, including R. humulis. Virginia is near the northern limit of its distribution in the southeastern states, and it is not surprising that the eastern harvest mouse does not breed in midwinter. Nothing is known of the energetics of reproduction in eastern harvest mice, or in Reithrodontomys in general, but with large litters and the small size of females, energy demands must be high. I would predict that Reithrodontomys will have lower metabolic rates than expected for their body weight, and thus they would be less efficient than Microtus in producing either heat or embryos.

In conclusion, the pattern of breeding in these three rodents is understood in the context of the distribution of the genus (boreal for Microtus and sub-tropical for Sigmodon and Reithrodontomys). Microtus, with its high metabolic rate and adaptations to conserve heat, is suited to breed even during the cool or cold months of the year. In fact, wherever it has been studied, Microtus usually has a breeding season that extends from March to October (Keller, 1985). This is longer than the breeding season of Sigmodon in eastern Virginia and probably longer than that of Reithrodontomys as well. Studies of reproduction in these two genera are more limited, but any breeding in the winter months would have to be viewed as exceptional.

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## Stimulation of Reproduction in *Peromyscus leucopus* and *Peromyscus maniculatus* With 6-MBOA in the Field

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### ABSTRACT

The addition of 6-MBOA to food supplements available to *Peromyscus* spp. in the field caused an increase in reproductive activity during midsummer. In 1983 *Peromyscus leucopus* and *Peromyscus maniculatus* with access to 6-MBOA had significantly more tertiary follicles and larger embryos in utero than those of control grids. Availability of 6-MBOA was also associated with increased litter size in *P. maniculatus* and larger testes in *P. leucopus*. In 1984, when only *P. leucopus* densities were adequate for data analysis, the results for both sexes were similar.

### INTRODUCTION

Short-lived rodents are known to respond to various environmental stimuli as a means of synchronizing their reproduction within environmentally favorable periods. *Peromyscus* spp. from more northern latitudes than Virginia have been shown to reproduce continuously once the breeding season commences (Miller et al., 1979). Extensive studies of *Peromyscus leucopus* and *Peromyscus maniculatus* at the University of Virginia Mountain Lake Biological Station, Giles Co., Virginia, have demonstrated that these species have bimodal breeding seasons with a midsummer cessation commonly occurring (April-June and September-October; Wolff, 1986a, b). Similar bimodal reproductive seasons have been reported for *Peromyscus* spp. from populations located in West Virginia (Sicher and Bradshaw, 1966; Cornish and Bradshaw, 1978), Michigan (Burt, 1940), New Jersey (Jackson, 1952), and Ohio (Rintamaa et al., 1976). Cornish and Bradshaw (1978) suggested that the apparent bimodality of reproductive activity results from a change in the overall population structure due to an influx of juveniles and subadults during the midsummer period. This change in population composition effectively masks ongoing adult reproduction. Wolff (1985), however, reported that adult female *P. leucopus* and *P. maniculatus* are not reproductively active during the midsummer period even though environmental conditions seem appropriate for continuous reproduction. Moreover, food supplementation on Mt. Lake study grids did not result in sustained changes in reproductive activity (Gerzoff, 1984; Wolff,



1986a). Consequently, the cause of the midsummer breeding hiatus in these species of Peromyscus remains unknown.

This research was initiated to determine whether plant secondary compounds that stimulate breeding activity reduce or eliminate the midsummer hiatus in Peromyscus reproduction. Green vegetation has been suggested as an important proximate factor in the regulation of rodent reproductive activity, especially in microtines. Sanders et al. (1981) summarized the effects of green vegetation on microtine reproduction and report the identification of the biologically active compound 6-methoxybenzoxazolinone (6-MBOA). They demonstrated clearly that ingestion or injection of 6-MBOA, extracted from winter wheat, has effects very similar to those reported from studies of the ingestion of green vegetation. Sanders et al. (1981) further suggested that this naturally-occurring nonestrogenic compound may serve as an environmental cue that stimulates reproduction. Berger et al. (1981) and Negus and Berger (1977) reported that the addition of 6-MBOA to the diet of reproductively inactive Microtus montanus results in the resumption of reproductive activity in the field during winter. These results show clearly that this compound can over-ride environmental variables that normally inhibit reproduction (e.g., photoperiod, low quality food resources). If midsummer photoperiods inhibit reproduction of Peromyscus or if field diet quality changes biochemically, then the addition of 6-MBOA to field diets could result in increased reproduction during the midsummer breeding hiatus.

#### MATERIALS AND METHODS

This study was conducted at the Mt. Lake Biological Station in Giles Co., Va (37° 10' N, 80° 30' W; elevation-1200 m) in an oak-maple-hickory forest with a rhododendron-blueberry-fern understory. The average temperature during summers of the study was 18°C. A detailed description of vegetation and climate can be found in Stephenson (1982).

The study area consisted of two 1-ha grids and one 3-ha grid in 1983 and five 1-ha grids in 1984. All grids were spaced approximately 100 m apart. Each 1-ha grid contained 64 trap stations and 64 food hoppers similarly placed. Hoppers (glass cylinders 18 cm x 7.5 cm) had one open end and contained 30 g of food when full. Control and experimental grids had food hoppers placed on the grids for one month during the summer breeding hiatus (1983, July 3 to August 12; 1984, July 8 to August 10). During this study period, hoppers were replenished daily with experimental or control chow. Experimental chow was composed of uniformly ground Pro lab 3000 mouse chow to which 40 µg of 6-MBOA per gram of chow was added. The coating of chow with 6-MBOA followed the methods of Berger et al. (1981). The control diet was coated in the same manner except that 6-MBOA was omitted from the solvent.

Animals were live-trapped on each grid for two days at 2-4 week intervals from March through November of 1983 and 1984. Trap stations were positioned in an 8 by 8 (1-ha grids) or 14 by 14 (3-ha grid) array with traps spaced 12.5 m apart. Captured animals were ear-tagged for individual identification and data on size, age, and reproductive condition were recorded following the methods of Wolff (1985, 1986a). In August 1983 and 1984 animals were snap-trapped on each grid, as well as in areas adjacent to the grids, in order to evaluate the condition of specific organs (testes, seminal vesicles, ovaries, uterus, and adrenals). Adjacent areas were similar in habitat and located within 300 m of the study grids and, therefore, the entire area was considered a single demographic unit (*sensu* Lidicker, 1978). Organ and tissue masses were measured for each animal. Histological

**Table 1.** For 1983 comparisons of body mass, reproductive organ masses, number of tertiary follicles, litter size in-utero, and crown-rump length of embryos for P. leucopus and P. maniculatus with or without access to 6-MBOA in the field. E = 6-MBOA grids, C = control grids, N = number of animals, with data presented as mean  $\pm$  S.D. Statistical significance is denoted by asterisks at (\*)  $p \leq 0.05$ , (\*\*)  $p \leq 0.01$ , (\*\*\*)  $p \leq 0.001$ .

<u>P. leucopus</u>		
	E	C
<b>Nonpregnant Females</b>		
N	14	12
Body mass (g)	19.4 $\pm$ 4.6	22.3 $\pm$ 3.6
Uterine mass (mg)	505 $\pm$ 206	465 $\pm$ 125
Ovarian mass (mg)	123 $\pm$ 27	115 $\pm$ 47
Tertiary follicles (#)	4.5 $\pm$ 0.6**	3.0 $\pm$ 0.8
<b>Pregnant Females</b>		
N	5	10
Body mass (g)	20.2 $\pm$ 1.3	21.1 $\pm$ 2.1
Litter size	4.0 $\pm$ 0.6	3.6 $\pm$ 0.8
Embryo length (mm)	16.6 $\pm$ 2.2***	9.5 $\pm$ 2.3
Tertiary follicles (#)	4.6 $\pm$ 0.4***	2.8 $\pm$ 0.6
<b>Males</b>		
N	11	6
Body mass (g)	19.2 $\pm$ 2.6	21.8 $\pm$ 3.3
Testes mass (mg)	2958 $\pm$ 968*	1826 $\pm$ 700
Seminal vesicle mass (mg)	2971 $\pm$ 1180	2076 $\pm$ 831
<u>P. maniculatus</u>		
	E	C
<b>Nonpregnant Females</b>		
N	--	--
Body mass (g)	--	--
Uterine mass (mg)	--	--
Ovarian mass (mg)	--	--
Tertiary follicles (#)	--	--
<b>Pregnant Females</b>		
N	7	8
Body mass (g)	17.5 $\pm$ 2.0	19.1 $\pm$ 1.2
Litter size	3.9 $\pm$ 0.4*	3.2 $\pm$ 0.4
Embryo length (mm)	12.6 $\pm$ 1.6**	6.8 $\pm$ 3.4
Tertiary follicles (#)	4.7 $\pm$ 0.5***	3.0 $\pm$ 0.5
<b>Males</b>		
N	6	8
Body mass (g)	17.5 $\pm$ 2.0	19.1 $\pm$ 1.2
Testes mass (mg)	2410 $\pm$ 605	2562 $\pm$ 309
Seminal vesicle mass (mg)	2199 $\pm$ 869	1859 $\pm$ 734

sections of the ovaries were examined and the number of tertiary follicles was recorded. Uteri were examined for embryos and implantation scars or sites. Crown-rump measurements were made on all embryos greater than 3 mm in length. In September of 1984 a second sample of snap-trapped animals from the adjacent areas was examined to assess reproductive activity.

Data were analyzed using the SAS statistical package. Differences in reproductive characteristics between animals from experimental and control grids were tested by t-tests and

**Table 2.** For 1984 comparisons of body mass, reproductive organ masses, number of tertiary follicles, litter size in-utero, and crown-rump length of embryos for P. leucopus with or without access to 6-MBOA in the field. E = 6-MBOA grids, C = control grids, N = number of animals, with data presented as the mean  $\pm$  S.D. Statistical significance is designated by asterisks at (\*)  $p \leq 0.05$ , (\*\*)  $p \leq 0.01$ , (\*\*\*)  $p \leq 0.001$ .

	E	C
<b>Nonpregnant Females</b>		
N	8	12
Body mass (g)	19.4 $\pm$ 2.9	18.1 $\pm$ 3.3
Uterine mass (mg)	539 $\pm$ 229	435 $\pm$ 195
Ovarian mass (mg)	133 $\pm$ 45*	94 $\pm$ 44
Tertiary follicles (#)	3.2 $\pm$ 2.4**	0.3 $\pm$ 0.8
<b>Pregnant Females</b>		
N	6	5
Body mass (g)	19.9 $\pm$ 1.1	22.1 $\pm$ 3.0
Litter size	4.0 $\pm$ 1.7	2.8 $\pm$ 1.6
Embryo length (mm)	19.6 $\pm$ 2.4***	6.1 $\pm$ 1.3
Tertiary follicles (#)	4.6 $\pm$ 0.9*	2.9 $\pm$ 1.3
<b>Males</b>		
N	26	25
Body mass (g)	21.5 $\pm$ 3.0	20.2 $\pm$ 3.0
Testes mass (mg)	2693 $\pm$ 1453**	1992 $\pm$ 582
Seminal vesicle mass (mg)	2477 $\pm$ 1371	2145 $\pm$ 737

considered statistically significant at  $p \leq 0.05$ . Due to small sample sizes on treatment grids, grids were combined for all analysis.

## RESULTS

Live-trapping during the course of the 1983 6-MBOA exposure period (July 3-August 12) showed that the proportion of pregnant or lactating females on both control and experimental grids increased after the July 27 sample and through the end of the exposure period. All P. maniculatus in the kill sample (August 12) were pregnant but differed significantly between diet treatment. The number of tertiary follicles, implanted embryos, and embryo length were all significantly greater for animals with access to the 6-MBOA diet (Table 1). Among P. leucopus, all females were either pregnant or entering into a preovulatory phase, but follicle numbers differed significantly according to the diet treatment (Table 1). As with P. maniculatus, embryos from females with access to 6-MBOA were significantly longer in crown-rump length than from females on the control grids, indicating an earlier onset of reproductive activity. Among males, diet treatment was associated with differences in testes mass only in P. leucopus and had no effect on seminal vesicle mass in either species (Table 1). Among males and females of both species no significant differences occurred in body mass, total length, or adrenal mass between grids.

During 1984 Peromyscus spp. were exposed to 6-MBOA from July 8, when none of trapped animals were visibly pregnant until

August 10. Two equally-spaced trapping events during this period revealed only one pregnant *P. leucopus* prior to the August 10-12 snap-trapping session. Over the study period, no statistical differences in body mass, body length, or external signs of reproductive activity occurred between samples or between study sites. The results of data analyses for all *P. leucopus* removed from the study grids are reported in Table 2. These data, categorized by female condition, clearly indicate that reproduction was initiated earlier on the experimental grids. Pregnant females from experimental grids had more implanted embryos and more tertiary follicles that could ovulate during a postpartum estrus than females from control grids. In addition, the greater length of embryos from experimental grids indicate that these females were much further into a gestation cycle than control females. Among nonpregnant animals, the virtual absence of tertiary follicles in ovaries from control animals provides further support for the effect of diet (6-MBOA). Among male *P. leucopus*, animals from experimental grids had significantly larger testes than control males, but they did not differ in any other parameter. Insufficient numbers of *P. maniculatus* were captured for data analysis during the 1984 study period. However, reproductive organ masses, the number of tertiary follicles, and the number and length of embryos all tended to be greater in females with access to 6-MBOA than in those without 6-MBOA.

A field sample taken from comparable and adjacent habitats to the grids, on September 9, revealed that all females of both species (total  $n=13$ ) were in an early stage of pregnancy and all males (total  $n=12$ ) had large scrotal testes. Litter size in *P. leucopus* averaged 4.0 and in *P. maniculatus* averaged 4.1. In both species embryos averaged 13 mm in length.

#### DISCUSSION

Throughout North America mid- and low latitude populations of *P. leucopus* and *P. maniculatus* exhibit a midsummer lull in reproduction, as previously cited. The occurrence of this hiatus follows summer solstice and the onset of decreasing photoperiods, and is prior to the major period of seed, fruit, and nut production. The results of these summer field studies, centered upon the midsummer reproductive lull, clearly demonstrate that the addition of a naturally-occurring stimulatory compound, 6-MBOA, causes a resumption and/or increase in reproductive activity. Male *P. leucopus* and *P. maniculatus* with access to 6-MBOA have greater testes mass, whereas in females the number of tertiary follicles is significantly greater than that of controls. Additionally, in pregnant animals of both species, access to 6-MBOA is associated with litter sizes 11-43% larger and embryos 75-220% longer than controls.

Because animals of control and experimental grids did not differ in body mass or length, the variation in litter and embryo size cannot be attributed to maternal size differences. Differences in embryo size could be due to variation in rates of embryological development. However, the magnitude of change would require growth rates two to three times above normal, an unlikely event. The most probable explanation for the marked differences in embryo size between grids is an earlier onset of reproductive activity in females with access to 6-MBOA followed by normal rates of embryonic development. Assuming a direct 1:1 relationship between length of embryos and the corresponding uterine swellings, the age of embryos was estimated from the data of Layne (1968). The difference in embryo length between control and experimental animals represents a 10 to 14 day difference in the dates of conception. Given that the exposure period was approximately 30d in duration, animals with access to 6-MBOA must have initiated

follicle development, mated, and begun embryonic development within the first 15 days of exposure. Field studies of Microtus montanus in winter demonstrated similar rapid responses to 6-MBOA (Berger et al., 1981; Negus and Berger, 1977). Laboratory studies have shown that reproductive organ development of microtine rodents is significantly affected after just 3 days of intraperitoneal injection of this stimulatory compound (Sanders et al., 1981; Cranford, 1983). Also, plant parts, including specific flowers and seeds, have been shown to contain steroidal estrogens that may have the potential to trigger reproduction (Gawienowski and Gibbs, 1969). Experiments with gibberellic acid, a plant hormone, have caused laboratory-caged wild Mus musculus to rapidly initiate reproduction, resulting in a doubling of the number of breeding females (Olsen, 1981). These studies all demonstrate strong reproductive response by rodents to small amounts of hormone-like substances from plants. As shown in this study, plant stimulatory compounds can over-ride the inhibitory effects of whatever variables normally cause a midsummer reproductive lull in Peromyscus spp.

Plant compounds of an inhibitory nature may also be involved with the midsummer reduction in reproductive activity of Peromyscus spp. In the laboratory, ingestion of the inhibitory compounds 4-vinylguaiacol, 4-vinylphenol, or p-coumaric acid by adult and juvenile Microtus montanus results in reduced follicle production in adults and delayed sexual maturation in juveniles (Berger et al., 1977). In addition, these adults produced fewer young per litter and had fewer secondary follicles. Over a 100-day test period, the percent of females reproducing declined from 91% to 58%. Subsequent research has demonstrated that these inhibitory compounds have similar effects in Microtus pennsylvanicus from Virginia (Cranford et al., 1980). These studies suggest that seasonal declines in reproduction in Peromyscus spp. may be partially due to changes in the presence of inhibitory compounds in their plant food resources.

Thus, modulation of reproduction may occur due to changes in the dietary intake of stimulatory and inhibitory plant compounds. The addition of 6-MBOA to Peromyscus diets in the field may have reduced the ratio of inhibitory to stimulatory compounds ingested, thereby enhancing reproductive activity. Negus et al. (1977) have shown that reproductively quiescent populations of Microtus montanus resume reproduction if grass germination occurs following an autumn drought period. These grasses have been found to contain inhibitory compounds when senescent and stimulatory compounds when in active vegetation growth (N. C. Negus, pers. comm.). Consequently, stimulatory plant compounds appear to over-ride the inhibiting reproductive effects of some phytochemicals and photoperiods.

### CONCLUSIONS

This research has demonstrated that the addition of 6-MBOA to food supplements in the field results in a rapid resumption of reproductive activity and the production of relatively larger litter sizes in two Peromyscus species. It has not, however, answered the question of what causes reduced reproduction in the summer. Further study of photoperiodic and phytochemical effects and their interaction on reproductive parameters are required to more fully understand the dynamics of Peromyscus reproductive activity.

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## Food Habits of the Big-Eared Bat, *Plecotus townsendii virginianus*, in Virginia

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### Abstract

Food habits of a maternity colony of *Plecotus townsendii virginianus* (Handley), determined by analyzing fecal pellets in a three-year study, demonstrated that moths (Lepidoptera) comprised the majority of this bat's diet. Moth consumption was greatest in late summer. Beetles (Coleoptera) were a distant second in food importance. Small quantities of Homoptera, Neuroptera, Tricoptera and Plecoptera were also consumed.

### Introduction

The Virginia big-eared bat, *Plecotus townsendii virginianus*, is in need of special protection. Hall and Harvey (1977) petitioned the U.S. Fish and Wildlife Service to list this subspecies as endangered under the Endangered Species Act because of its limited distribution, small population size, and concentration of individuals in a few caves which increases its vulnerability to human disturbance. Consequently, *P. t. virginianus* was placed on the Fish and Wildlife Service's list of Endangered and Threatened Wildlife and Plants in 1979. Many aspects of the natural history of *P. t. virginianus* are poorly understood or are conjectured from other subspecies or related species. For effective protection and management, it is essential that the life history of this species be delineated.

The first observation of foods eaten by the big-eared bat were incidental to a food habits study of the big brown bat, *Eptesicus fuscus*, (Hamilton, 1933). Hamilton found evidence of moths in the stomach and feces from a single big-eared bat believed to be from West Virginia, presumably *P. t. virginianus*. Ross (1967) analyzed the contents of digestive tracts of 38 *P. townsendii* and 25 *Plecotus phyllotis* from Arizona and New Mexico. In 35 of the *P. townsendii*, he found small lepidopterans, 3 to 10 mm in length (mean about 6 mm). Coleopteran parts were found in two bats. He reported 6 to 12 mm moths in all 25 of the *P. phyllotis* examined with four of the bats containing coleopterans and flying ants. In New Mexico, Black (1974) found that moths predominated (100%) in the fecal pellets of three *P. phyllotis*. In Oregon, Whitaker, Maser and Keller (1977) and Whitaker, Maser



and Cross (1981) found the stomachs of 15 P. townsendii contained 100% moths while one stomach contained 95% moths and 5% hemipterans. Feces of one P. townsendii contained only moths. Also in northern Arizona, Warner (1985) found 100% moth remains in feces of three Plecotus.

As part of a comprehensive study of the life history and foraging ecology of P. t. virginianus in Virginia, we conducted a three-year study of its food habits. The results are reported in this paper.

### Materials and Methods

Study area -- The only known maternity colony of Plecotus townsendii virginianus in Virginia roosts in a limestone cave in southwestern Virginia (945 m). The site is an anticlinal valley of the Ridge and Valley Physiographic Province of the Mixed Mesophytic Region (Hoffman, 1979). Nearly the entire valley is devoted to agriculture, including pastureland, hayfields, and row crops. There are few human residences. The cave is in the middle of a pasture of gently rolling hills and sinkholes with a small permanent stream flowing into an adjacent cave. This stream flows from the nearest forested area, about 0.8 km from the cave. The slopes of the mountains forming the valley are dominated by beech (Fagus grandifolia) and red maple (Acer rubrum).

Guano collection -- The colony of bats was monitored (by VMD) in 1983-1985 from mid-March, when bats begin to arrive from their hibernacula, through mid-October when most bats have left the maternity cave. Plastic sheets for collecting feces were placed in the cave below roost sites and in flyways. Fecal pellets were usually gathered weekly. When bats did not use the expected roost sites, little or no guano was collected.

Fecal analysis -- The techniques used were those of Brack and LaVal (1985). Feces were air-dried in labeled glassine envelopes. In the laboratory, fecal pellets were placed on a petri dish, wetted with a 50:50 ethanol:water mixture, and each pellet teased into a uniform monolayer. A 10 to 25x dissecting microscope was used in the identification of insect parts. Insect fragments typically available for identification were wings, antennae, legs, mouthparts, scales, hairs and eyes. In most cases, insects could only be identified to order. Percentage volume for each insect order was estimated for each fecal pellet. Estimates were made by teasing the pellet into a monolayer, separating the various parts, and placing them over a fine grid graph paper for comparison. With practice, the use of graph paper was reduced. The volume of each order of insect in the diet was expressed as a percentage of the composite diet on that sample date.

An analysis of variance on arcsine-transformed data was conducted on the diets among months. Cochran's C-test for homogeneity of variance substantiated the need for transformation. Scheffe multiple range tests detected differences among groups (0.01 level). Statistical analyses were performed on a Data General MV/10000 using SPSS-X Release 2.0A for Data General AOS/VS at Radford University.

### Results

Eight orders of insects were represented in the feces: Lepidoptera (moths), Coleoptera (beetles), Diptera (flies, midges, mosquitoes, gnats), Hymenoptera (flying ants), Homoptera (leaf hoppers), Neuroptera (lacewings), Tricoptera (caddisflies), and Plecoptera (stoneflies).

Of the 1222 fecal pellets analyzed, 823 contained only

Table 1. The summer diet by month, 1983 through 1985, of *P. t. virginianus*, Tazewell County, Virginia. Diet is presented by percent volume for six orders of insects. The category "Other" denotes hair,vegetable material,and Tricoptera and Plecoptera (two aquatic-based insect orders that do not seem to be important to these bats). N = number of fecal pellets.

Date	N	Lepidoptera	Coleoptera	Diptera	Hymenoptera	Homoptera	Neuroptera	Other
(1983)								
June	54	87.0	12.3	0.1		0.2	0.1	0.3
July	24	94.8	3.1	0.4		0.4		1.3
Aug	18	96.4	1.1		1.7	0.3		0.5
Sept	2	87.5	2.5		10.0			
(1984)								
Apr	44	95.7	3.3	0.3				0.7
May	129	96.4	2.0	0.2			0.2	1.2
June	266	98.6	1.2	0.0*				0.2
July	41	98.5	1.0			0.4		0.1
Aug	157	98.2	0.4	0.5	0.1	0.6		0.2
Sept	16	98.1				0.6		1.3
(1985)								
Apr	16	97.2	2.8					
May	89	97.4	0.7	1.6			0.2	0.1
June	196	96.6	2.6	0.4	0.1	0.3		
Aug	94	99.4	0.3	0.2			0.1	
Sept	73	97.1	0.6	2.2		0.1		
	1222	97.1	1.9	0.4	0.1	0.2	0.0*	0.3

\* = trace, less than 0.1%

lepidopterans, 256 contained at least 95% lepidopterans, and only 18 pellets contained less than 80% lepidopterans (Table 1). Coleopterans, although much less important than lepidopterans, were consumed throughout the season and were the second most common dietary item. The occurrence of insects from other orders in the diet was infrequent and sporadic with no apparent pattern or trend. Although fecal insect remains were generally characterized only to the ordinal level, a family of homopterans (Pentatomidae), a family of hymenopterans (Formicidae) and the Asiatic oak weevil (Coleoptera: *Cyrtopistomus castaneus*) were specifically identified. Remains of a mite were found in one fecal pellet. Two wings of a moth from the family Noctuidae were collected from beneath a roost site. Occasionally, non-insect material, including vegetation fragments, hair and mucus were found in the feces.

Dietary differences among months were detected from the fecal samples. Lepidopterans were a larger percentage of the diet in August than in May and June. Coleopterans were eaten more often in June and April than in May, August and September. More dipterans were consumed in September than in June. No differences were detected among months in frequencies of Hymenoptera, Homoptera and Neuroptera ( $P = 0.01$ ). This reflects the high variance in the small quantities of insects from these orders in fecal samples rather than uniform consumption throughout the season.

### Discussion

Numerous studies of bat food habits have been conducted, and the validity and applicability of the various techniques is of particular concern. Ross (1967) concluded that fecal pellets yielded similar information as stomach contents only if contamination of fecal pellets by wastes of other animals was avoided. Based on these conclusions and the apparent lack of digestive chitinase by vertebrates (Snodgrass, 1935), the technique was widely used. Later, chitinase activity was found in some species (Jeniaux, 1961), but the rapid rate of food passage in most insectivorous bats (Buchler, 1975) limits the time available for chitinase activity. Whitaker, Maser and Cross (1981) compared stomach and fecal analyses. They found moths and beetles more abundant in feces than in stomachs, with the potential to overestimate them with fecal analysis. In contrast, homopterans and dipterans were sometimes over-represented and sometimes under-represented in fecal pellets. Griffith and Gates (1985) compared feces and stomach contents and found no significant difference between the two. In separate blind studies, Rabinowitz and Tuttle (1982) and Kunz and Whitaker (1983) tested the reliability of fecal analysis. Tuttle and Rabinowitz (1982) concluded that fecal analyses can be very misleading, especially when both soft- and hard-bodied insects are eaten. In contrast, Kunz and Whitaker (1983) concluded that if the sample size is large enough, fecal analysis can be a reasonably reliable indicator of food eaten by bats. Similarly, Swift, Racey and Avery (1985) were able to distinguish soft- and hard-bodied insects from fecal remains.

In the present study, the use of fecal analysis, rather than analysis of stomach contents, was essential since stomach analysis requires that bats be killed, which is neither desirable or possible with endangered bats. The fecal pellets collected from early to mid-summer were from an unknown number of individuals, most of which were pregnant females. From mid-summer until the end of the season, the feces were from an unknown number of individuals likely to contain both mothers and their young. Therefore, it is not known if this collection represents a biased sample. However, in the absence of other evidence, we feel that our samples are representative of the colony. Collection of samples from individual bats caught at the cave entrance may disturb the bats and cause their abandonment of the nursery colony.

Moths are important in the diet of many insectivorous bats (Ross, 1967; Whitaker, 1972; Black, 1974; Warner, 1985; Griffith and Gates, 1985; Brack and LaVal, 1985), including P. t. virginianus in the present study. Plecotus townsendii virginianus females and their offspring are moth specialists. While this was predicted, based upon studies of other subspecies (Ross, 1967; Whitaker, Maser, Keller, 1977; Whitaker, Maser, Cross, 1981) and similar species (Ross, 1967; Warner, 1985), this study provides specific dietary information which should contribute to the management and protection of this subspecies. Our study further substantiates that the species is a moth specialist throughout its large range despite the spotty distribution and the geographical isolation of the subspecies.

It may be that moths are more readily available to P. townsendii than other insects due to abundance, active periods, or ease of capture. Ross (1967) stated that bats collected during the daytime have empty stomachs; 20 of the 38 Plecotus townsendii he examined had relatively empty stomachs. Many of these bats were collected early in the evening prior to foraging (Jones, 1965). Plecotus is reported as a late flier (Dalquest, 1947; Cockrum and Cross, 1964; O'Farrell and Bradley, 1970; Jones, 1965; Kunz and Martin, 1982). Bats of the study colony in Virginia generally emerged about two hours after sunset when

moths are more active than other insects (Williams, 1939; Belwood, 1979), which provides a circumstantial relationship between predator and prey. Several studies in varied habitats have found that moths are more readily available in the latter part of the summer (Black, 1974; Belwood, 1979; Brack and LaVal, 1985). Although we did not sample prey availability in the foraging area, a similar late season increase in moth availability may account for a greater percentage of moths in the diet in August than in May and June.

Coleopterans were the second most frequently identified dietary item. Ross (1967) found similar results for P. townsendii; coleopterans were found in feces more frequently late in the season. Although this may reflect their availability, coleopterans were not found to be more abundant late in the season by Black (1974), Belwood (1979) and Brack and LaVal (1985). P. t. virginianus ate more dipterans in September than in June. Because Black (1974) and Belwood (1979) captured more Diptera in September than June, we suspect the bats may be responding to increased dipteran availability. Reliable extrapolation of these observations awaits, however, the simultaneous delineation of foraging habitat and patterns of prey availability and consumption.

The hair found in some feces was probably ingested while grooming. Vegetation fragments may have been ingested incidentally during the capture of insects, or they may have been mistaken as insects. If P. t. virginianus gleans insects from vegetation, occasional leaf fragments may be ingested during capture of resting insects. The European Plecotus are known to take insects from leaves (Howell, 1920).

A great deal is yet to be learned about this endangered species. Plans for future studies include a determination of the foraging habitat with simultaneous sampling of insect availability and insect consumption. We hope to address the topic of foliage gleaning by the bat and will attempt to locate night roosts if they are used. With observations from the cave and night roosts, active periods can be delineated and related to insect abundance or behavioral phenomena.

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## Application of Input-output Analysis to Community Matrix Models

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### ABSTRACT

Ecological applications of input-output analysis have been previously limited to food webs, resources and energy flows or incorporated into hypothesis about community successional development. We propose that with the large population and habitat variable data sets for avian and mammalian communities, the application of input-output analysis to these data sets could enhance our knowledge of species affects and effects. This paper reports how this analysis would be set up and applied. Application of this analysis will not only give direct effects of one species on another but also indirect effects through other species in a causal chain. Further this permits a measure of the intensity of interactions within a community. This measure could then be applied to the comparison of different communities or groups of taxa within a community with respect to the overall intensity of interspecific interactions.

### INTRODUCTION

Theoretical analyses of competitive interactions have commonly invoked the Lotka-Volterra competition model as a reasonable approximation of natural system behavior (Levins 1968, Vandermeer 1970, MacArthur 1972, May 1974). Despite discussions of theoretical and philosophical limitations (Kerner 1957, Leigh 1965, Smith et al. 1975, Wiegert 1979), the model has often been utilized to describe two-species competitive situations (Vandermeer 1970, Harper 1979). In addition, generalizations of the Lotka-Volterra equations to n-species systems have resulted in community models employing matrices of competition coefficients (Levins 1968, May 1974). In equilibrium systems, competitive relationships may be expressed as a single matrix equation  $K = AN$  where  $K$  is a column vector of carrying capacities,  $N$  is the column vector of population densities at equilibrium and  $A$  is a square matrix of competition coefficients ( $\alpha_{ij}$ 's referred to as the "community matrix" [Levins, 1968]). Analysis of the community matrix can provide valuable information about community stability and the maximum number of species in a stable community (Vandermeer 1972, May 1974, 1981), while the  $\alpha_{ij}$ 's themselves provide information about species interactions (Seifert and Seifert 1976).

Vandermeer (1969) was one of the first investigators to apply theoretical community formulations to actual data, when he grew four species of ciliate protozoans in individual and mixed cultures and calculated the resulting interaction coefficients ( $\alpha_{ij}$ 's). Levins (1968) used nonmanipulative data on Drosophila species co-occurrence to estimate  $\alpha_{ij}$ 's and MacArthur (1968)

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\* Deceased.

employed co-occurrence data to construct a community matrix for warbler species. The community matrix has been further applied to studies of cave crustaceans (Culver 1970, 1973) and insects living on Heliconia species (Seifert and Seifert 1976). One problem with straightforward application of matrix analysis is the

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occurrence of first order nonlinearities in competitive interactions as have been shown by Ayala (1969) and Gilpin and Justice (1972) for competition between species of Drosophila. Further reports by Ayala, Gilpin and their colleagues have attempted to ascertain the bases for the nonlinearities (Ayala et al. 1973, Gilpin and Ayala 1973, Pomerantz et al. 1980). First order nonlinearities in species interactions, however, do not prohibit prediction of the behavior of competitive systems based on mathematical population models (Richmond et al. 1975) but do detract from the usefulness of linear matrix analysis in modelling such systems.

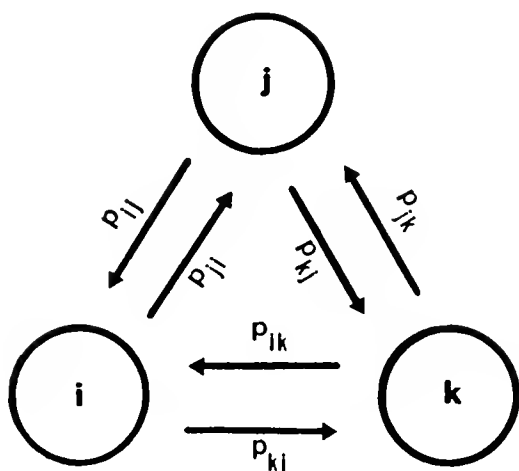
Fortunately, there is an approach to matrix analysis, namely input-output analysis, which is not affected by nonlinearities in the functions describing component interactions. Input-output or flow analysis has its origins in economics (Chenery and Clark 1959, Leontief 1966) and was introduced to ecological systems by Hannon (1973). Finn (1976) discussed ecological applications of input-output analysis at length and, together with his colleagues, has applied the approach to a series of ecological systems (Patten and Finn 1979, Finn 1980, 1982, Finn and Leschine 1980). Others have found flow analysis useful for describing ecosystem structure in tropical rainforest (Jordan 1982), lake (Richey et al. 1978) and swamp (Patten and Matis 1982) ecosystems. In general, ecological applications of input-output analysis have been limited to food webs (Levine 1980), resources (Barber 1978a, 1978b, Harrison and Fekete 1980), and energy flows (Hannon 1979). The input-output approach also has been applied and incorporated into hypotheses about community successional development (Ulanowicz 1980, Finn 1982). No attempt has been made to apply input-output analysis to matrix models of community interactions although the approach is suitable for distributive flows of information and causality (e.g., competitive effects) as well as conservative energy-matter flows (Patten et al. 1976).

This manuscript reports how input-output analysis would be set up and applied to field data sets. The necessary matrices and their subsequent modifications are set out and additional steps to evaluate other parameters are presented. The use of input-output analysis will yield direct as well as indirect species interaction effects. These measures will permit more complex relationships within species groups to be analyzed and understood. Further community level interactions can be determined which then permits different communities to be compared more directly.

### METHODS, MATERIALS AND RESULTS

Input-output analysis begins with construction of a matrix of flows from one ecosystem component to another (Hannon 1973, Finn 1976). This matrix is called the production matrix  $P$  (Hannon 1973). In the context of community interactions,  $P$  is not a matrix of flows but a matrix of causal effects (sensu Patten et al. 1976). In other words, element  $p_{ij}$  of  $P$  represents the instantaneous effect of the population of species  $j$  on the population of species  $i$ . The effect may be negative, indicating competition between  $i$  and  $j$  or predation or parasitism of  $j$  on  $i$ . If the effect is positive,



**Figure 1.**

A hypothetical community composed of 3 competing species showing causal pathways.

it indicates mutualism between  $i$  and  $j$  or predation or parasitism of  $i$  on  $j$  while a zero effect indicates no interaction between the two species. Instantaneous causal effects,  $p_{ij}$ 's may be calculated directly from the matrix of community coefficients ( $\alpha_{ij}$ 's) as follows,

$$p_{ij} = \alpha_{ij} N_j$$

where  $N$  is the number of individuals in the population of the  $j$ th species. A square ( $n \times n$ )  $P$  matrix of causal effects may be constructed accordingly where  $n$  is the number of species in the community:

		SPECIES $j$				
		1	2	...	$n$	
SPECIES $i$	1	$P_{11}$	$P_{12}$	...	$P_{1n}$	$T_1^*$
	2	$P_{21}$	$P_{22}$	...	$P_{2n}$	$T_2^*$
	.	.	.	.	.	.
	.	.	.	.	.	.
	$n$	$P_{n1}$	$P_{n2}$	...	$P_{nn}$	$T_n^*$
		$T_1^{**}$	$T_2^{**}$	...	$T_n^{**}$	TSC

where:

$p_{ij}^*$  = instantaneous causal effect of species  $j$  on species  $i$ ,  
 $T_i^*$  = total causal effect of all species on species  $i$ ,  
 $T_j^{**}$  = total causal effect of species  $j$  on all species,  
 TSC = total system causation.

To analyze the dependency structure implied by the matrix of causal effects, each causal effect  $p_{ij}$  can be expressed as a fraction  $q_{ij}'$  of the total causal effect on species  $i$ :

$$q_{ij}' = p_{ij} / T_i^*$$

The square ( $n \times n$ ) matrix of  $q_{ij}'$  elements may be termed the fractional causal effect matrix  $Q'$ . Each element  $q_{ij}'$  denotes the ratio of the causal effect of species  $j$  on species  $i$  to the causal effect of all species on species  $i$ .

Until now only direct causal effects have been considered. In addition to direct effects, species may also influence each other indirectly as cause and effect are propagated along "serial dependency sequences" (Patten et al. 1976) or "causal chains" (Bunge 1959). Such sequences consist of a series of interaction effects. Species  $j$  may influence species  $i$  directly or by means of its effect on the population of species  $k$ . For example, suppose that species  $i$ ,  $j$  and  $k$  are all competitors with negative  $p_{ij}$ 's (Fig. 1). Then if the abundance of species  $j$  is reduced, species  $i$ 's population will be affected positively because of the reduction of direct negative (competitive) effect. However, the same reduction in  $j$  will also reduce competition on species  $k$ , allowing its population to increase. Greater numbers of  $k$  will result in increased competition on  $i$ . Thus, there is a causal chain between  $j$  and  $i$  of length two in addition to a direct path of length one.

In order to evaluate causal effects of species  $j$  on species  $i$  (relative to all effects on species  $i$ ) over causal chains of all path lengths, the matrix  $(I-Q')^{-1}$  is computed where  $I$  is an identity matrix of rank  $n$  (Patten et al. 1976). The elements  $(I-Q')^{-1}_{ij}$  of this matrix indicate the causal effect of species  $j$  on species  $i$  propagated over all possible causal sequences and relative to the effect of all species on species  $i$ . Thus these elements predict the effect of a change in the population size of  $j$  on the population of  $i$  within the context of an  $n$ -species community. Such information is clearly useful for the development of hypotheses for manipulative experiments on natural communities (e.g., species removal experiments). Alternatively, it may be desirable to determine the fraction of the total causal effect of species  $j$  on all species which directly affects species  $i$ . This fraction  $q_{ij}''$  is computed by dividing each element  $p_{ij}$  by the column totals  $T_j^{**}$  of the causal effect matrix  $P$ :

$$q_{ij}'' = p_{ij} / T_j^{**}$$

A square ( $n \times n$ ) matrix  $Q''$  of  $q_{ij}''$  elements may be termed the fractional causal affect matrix to distinguish it from the fractional causal effect matrix  $Q'$ . Each element  $q_{ij}''$  of  $Q''$  denotes the ratio of the direct causal effect of species  $j$  on species  $i$  to the direct causal effect of species  $j$  on all species. This quantity measures how much of species  $j$ 's direct impact on the community is directed toward species  $i$ .

To determine the causal effect of species  $j$  on species  $i$  relative to all effects produced by species  $j$  over all causal chains of all path lengths, the matrix  $(I-Q'')^{-1}$  is computed. The elements  $(I-Q'')^{-1}_{ij}$  of this matrix indicate the causal effect of species  $j$  on species  $i$  relative to the total effect of species  $j$  over all causal sequences in the community. As was the case for the  $(I-Q')^{-1}$  matrix, these elements may be used for developing hypotheses concerning the relative effects of a particular species on other species prior to manipulative field experiments. This apriori knowledge should result in precise definition of manipulative field experiments and predictions of outcomes of these field experiments.

## DISCUSSION

Avian and mammalian ecologists have in the past 20 years applied many analytical tools to evaluate associations of species and habitats. Their use requires large data sets on the individual species and habitats which are fortunately directly applicable to input-output analysis. Such analysis yields additional information not produced as a result of the more commonly applied analysis. Not only is a species direct causal

effect determined but indirect effects via other species can be evaluated. Other direct and indirect paths can also be evaluated through the construction of additional matrices.

In addition to hypothesis development, testing and evaluation, input-output analysis of community matrices provides a means of estimating the total intensity of causal interactions (competitive or otherwise) within a community. Total system causation, TSC, a measure of the intensity of interactions within a community, is calculated as:

$$TSC = \sum_{i=1}^N T_i^*$$

where  $T_i^*$  is the total causal effect of all species on species  $i$ . This measure is useful for comparing different communities or different groups of taxa within a community with respect to the overall intensity of interspecific interactions.

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## Life History Patterns in a Central Virginia Frog Community

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### Abstract

Anurans worldwide exhibit a wide variety of life histories and reproductive modes. This diversity has made it difficult to categorize these animals into a manageable number of discrete life history groups. Collins (1975), who focused his attention on local adaptations of eight anuran species, deduced there were two primary life history patterns exhibited by the community he studied. Data derived from a contrasting wet and dry, two year study of a central Virginia anuran community with twelve species are examined to determine if this more diverse assemblage can be similarly partitioned. Results indicate his dichotomies can be used with some modification to categorize the life histories of the Virginia community. Six species, Acris crepitans, Hyla crucifer, H. femoralis, Gastrophryne carolinensis, Pseudacris brimleyi, and P. triseriata, are characterized by small body size, small clutch size, probable early maturity, low adult survivorship, and relatively high subadult survivorship. Probability of metamorphosis is relatively certain for all but H. femoralis and G. carolinensis. Six other species, Bufo americanus, B. woodhousei, Hyla chrysoscelis, Rana catesbeiana, R. clamitans, and R. utricularia, are characterized by relatively large body size, large clutch size, delayed maturity, high adult survivorship, and relatively low subadult survivorship. Probability of metamorphosis is relatively uncertain. Group placement is speculative for some species because of insufficient data on key life history attributes, such as adult and subadult survivorship.

### Introduction

The study of life histories is a process seeking patterns in the complexity of plant and animal adaptations. The elucidation of these patterns provides insight into the evolution of organisms. Elucidation of patterns in anuran reproductive and life history modes has been approached from the worldwide perspective by Salthe (1969), Salthe and Duellman (1973), Salthe and Mecham (1974) and Duellman (1985). It is obvious from these papers and others (e.g., Crump, 1974; Duellman, 1978) that there is a great diversity of reproductive modes and life history strategies among and within lineages of these animals. Not only are these animals diverse reproductively, they also exhibit considerable diversity in the seasonal timing of when these activities occur. Anuran communities exhibit temporal partitioning in temperate areas (Blair, 1957, 1961; Heyer, 1976, 1979; Weist, 1982) and in the tropics (Dixon and Heyer, 1967; Heyer, 1973; Crump, 1974; Duellman, 1978). This diversity has made it difficult to "pigeon-hole" anurans into discrete groups based on similar life history strategies.

A different approach was taken by Collins (1975) who examined life history strategies in a single anuran community and formulated his interpretations based on Darwinian theory of evolutionary adaptations to local environments. He partitioned his Michigan community of eight species into two groups, those species whose

larvae experienced a low but certain probability of metamorphosis and relatively high subadult survivorship (designated here as Group I) and those species whose larvae experienced a low but uncertain probability of metamorphosis and relatively low subadult survivorship (Group II). These dichotomies correlated somewhat with aquatic habitat types in which the frogs bred and with the breeding season. Characteristics of Group I are temporary habitat, small adult body size, small clutch size, early maturity and low adult survivorship. Group II is characterized by permanent (sometimes temporary) habitats, large adult body size, large clutch size, delayed maturity and relatively high adult survivorship (Collins, 1975). These two sets of attributes are very similar to the correlates of  $r$  and  $K$  selection theory (Pianka, 1983).

In this paper I present the results of a study of one central Virginia community consisting of twelve species of anurans. Information gleaned from phenological and life history observations taken during contrasting wet and dry years, combined with other data from central Virginia, are used to examine life history strategies of these animals. My objective is to ascertain whether the dichotomous strategies proposed for the Michigan community of eight species by Collins (1975) can be used to categorize the more diverse Virginia community.

### Materials and Methods

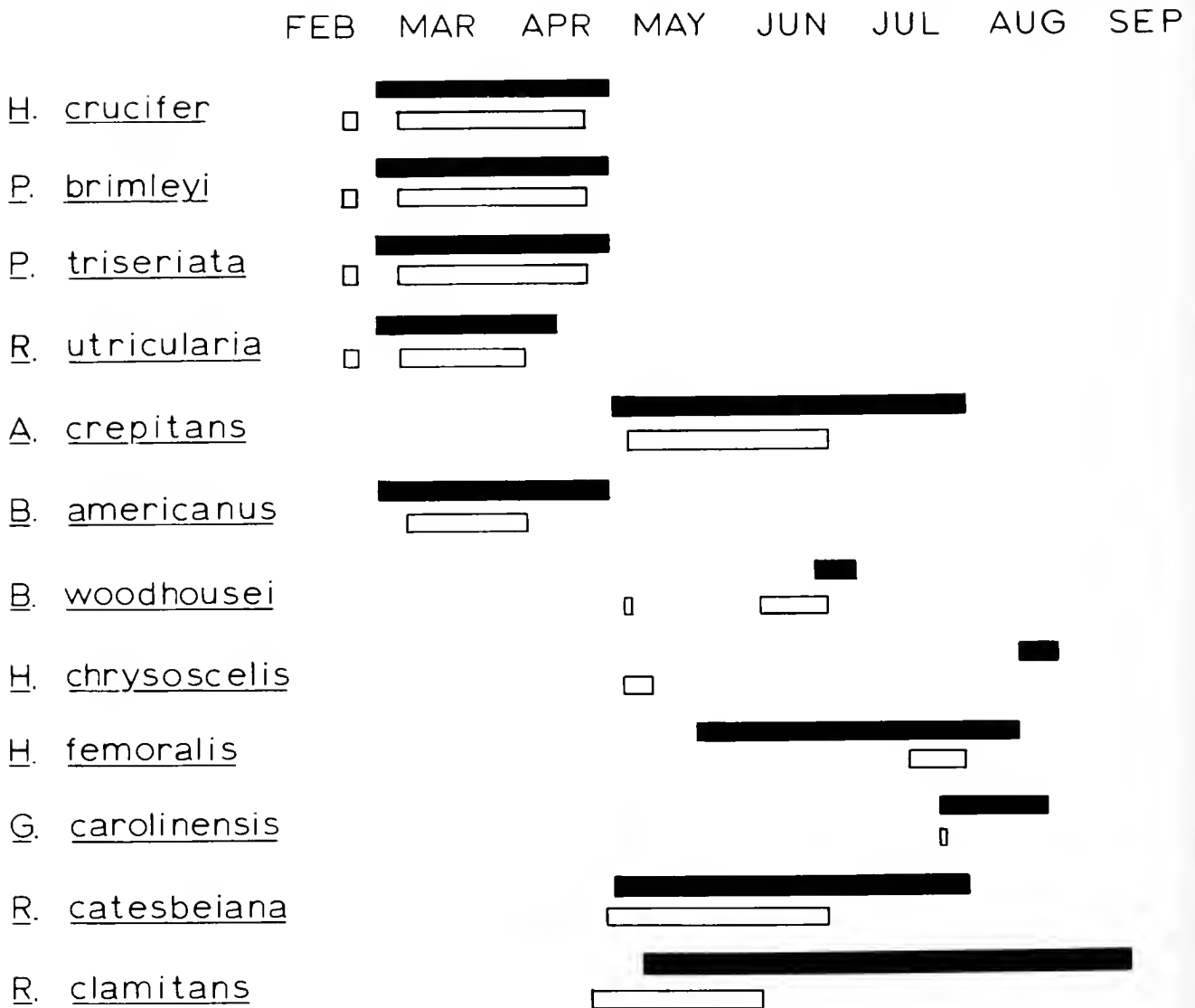
During March - September 1979 and March - August 1980 I obtained phenological data for an anuran community located 2 mi NE Chesterfield Court House, Chesterfield Co., Virginia. The twelve species were Acris crepitans (Northern Cricket Frog), Bufo americanus (American Toad), Bufo woodhousei fowleri (Fowler's Toad), Gastrophryne carolinensis (Eastern Narrow-mouthed Toad), Hyla chrysoscelis (Cope's Gray Treefrog), Hyla crucifer (Spring Peeper), Hyla femoralis (Pine Woods Treefrog), Pseudacris brimleyi (Brimley's Chorus Frog), Pseudacris triseriata (Upland Chorus Frog), Rana catesbeiana (Bullfrog), Rana clamitans (Green Frog), and Rana utricularia (Southern Leopard Frog). The site at Chesterfield County Airport is a grassy field at the southern end of the runway which contained varying levels of water (maximum = 0.75 m). The site is mowed irregularly when water levels allow. During the study period, grasses in some areas reached heights approaching 1 m. I visited the site on a weekly basis at night in 1979 and biweekly in 1980. I recorded the species present, those calling, and presence of amplexant pairs, eggs and recently transformed juveniles. I obtained periodic samples of tadpoles (preserved in 10% formalin) with dipnets. Call duration, egg-laying periods, length of larval period and dates of metamorphosis were determined from this information. Daily temperature and rainfall data were obtained from monthly climatological data summaries (Nat. Oceanic and Atmos. Admin., Vols. 89 - 90) for the nearest weather station at the time (Hopewell, 21 km SE of the study site).

Evaluation of the predictions noted above is primarily based on the results of the two-year field study, although some information has been gleaned from the literature and unpublished observations (J.C. Mitchell and C.A. Pague) from elsewhere in Virginia. Phenological terminology follows Mitchell (1979). Statistics were performed with SPSS programs (Nie, et al., 1976) following Zar (1974).

### Results

#### 1979 - 1980 Field Study

The Chesterfield Airport anuran community consisted of twelve species which fall into two groups based on seasonal occurrence



**Figure 1.**

Seasonal and annual variation in calling dates of twelve species of anurans at the Chesterfield County Airport site. Dark bar indicates periods of calling males for 1979 and the open bar calling periods for 1980.

(Figure 1). Early spring breeders at this site are *Hyla crucifer*, *Pseudacris brimleyi*, *P. triseriata*, *Rana utricularia*, and *Bufo americanus*. Males of these species called in March and April of both years and during a short warm period in mid-February in 1980 (Figure 1). There was little annual variation in initiation of calling periods among these species. Summer breeding anurans were *Acris crepitans*, *Bufo woodhousei*, *Gastrophryne carolinensis*, *Hyla chrysoscelis*, *H. femoralis*, *Rana catesbeiana* and *R. clamitans*. The timing of initiation of male vocalizations was variable among species in this group (Figure 1). Some started calling in late-April, while others were not heard until June or July. The most dramatic shifts in timing were exhibited by *Hyla chrysoscelis* and *H. femoralis*. On the other hand, *Bufo woodhousei* and *G. carolinensis* initiated calling in 1980 within one week of initiation in 1979.

Periods of egg-laying generally corresponded with call duration periods, but males usually called for varying periods of time before and after oviposition (Table 1). Egg-laying was not observed directly or indirectly in *H. chrysoscelis*, *B. americanus* and *B. woodhousei* and *P. triseriata*.

With two exceptions, metamorphosis occurred within the year of egg-laying. Larvae of *R. utricularia* which bred in September



Table 1. Dates of calling, egg-laying and metamorphosis for eight species of anurans at the Chesterfield County Airport site in 1979 and 1980. Duration is the period encompassed by the first and last recorded dates of male vocalizations.

Species	yr	Duration	Egg-laying	Metamorphosis
<u>H. crucifer</u>	79	1 Mar - 29 Apr	10 Mar - 22 Apr	12-20 May
	80	22 Feb - 22 Apr	7 Mar - 7 Apr	17 Apr
<u>P. brimleyi</u>	79	1 Mar - 29 Apr	10 Mar - 22 Apr	12-20 May
	80	22 Feb - 22 Apr	7 Mar - 7 Apr	17 Apr
<u>R. utricularia</u>	79	1 Mar - 15 Apr 1-23 Sep	1 Mar - 15 Apr 1-23 Sep	2 Jun - 7 Jul 17 May - 23 Jun <sup>a</sup>
	80	22 Feb - 7 Apr	22 Feb - 7 Apr	23 Jun
<u>A. crepitans</u>	79	29 Apr - 28 Jul	29 Apr - 29 Jul	May - 11 Aug
	80	3 May - 23 Jun	not obs	none
<u>H. femoralis</u>	79	6 May - 11 Aug	20 May - 11 Aug	16 Jun - 16 Sep
	80	14-28 Jul	22 Jul	none
<u>G. carolinensis</u>	79	22 Jul - 18 Aug	not obs	26 Aug - 9 Sep
	80	22 Jul	22 Jul	none
<u>R. catesbeiana</u>	79	29 Apr - 28 Jul	not obs	not obs
	80	27 Apr - 23 Jun	not obs	none
<u>R. clamitans</u>	79	6 May - 9 Sep	6 May - 16 Jun	not obs
	80	22 Apr - 6 Jun	22 Jul - 9 Sep not obs	not obs <sup>b</sup> 14 Jul

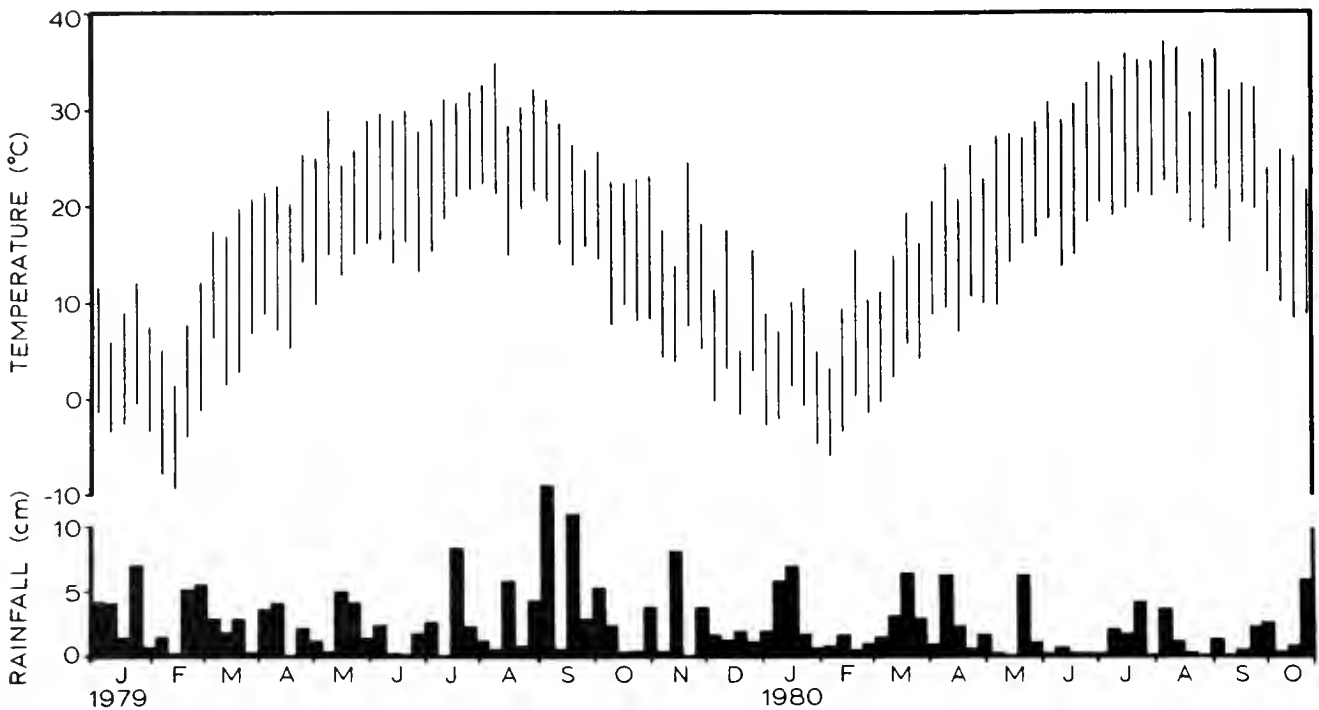
<sup>a</sup> 1980

<sup>b</sup> metamorphic individuals from 1979 cohort

1979 did not metamorphose until the following June and the July 1980 cohort of R. clamitans resulted from late-summer breeding activities in 1979. Metamorphic R. catesbeiana were not found, but the larval period may take up to two years (Collins, 1979; and references therein). Metamorphosis for the remaining species occurred 3-4 weeks after males ceased calling (Table 1).

#### 1979 and 1980 Weather Patterns

Comparisons between years of call initiation, duration, egg-laying periods, metamorphosis and survivorship (Figure 1, Table 1) demonstrate weather-dominated responses. Winter and early spring temperature and rainfall were similar in both years (Figure 2). Temperatures in the summer of 1979 were near normal, except during June which was cooler than average (June  $\bar{x}$  max/min = 29.0/15.3 C; 30 year  $\bar{x}$  = 31.0/18 C). Summer rainfall in 1979 (June-August, 34.0 cm) was about normal (30 yr  $\bar{x}$  = 35.9 cm) for that period. In 1980 mean June maximum temperature (31.1 C) was near normal (30.7 C) but those in July (34.7 C) and August (34.8 C) were above 30-year averages (Jul = 32.1 C; Aug = 31.2 C). Rainfall in June through August 1980 was 15.5 cm, less than half the amount for the same period in 1979. The July 1980 peak of 4.3 cm (Figure 2) resulted from one thunderstorm on the 23rd of that month.



**Figure 2.**

Weekly maximum and minimum air temperatures and rainfall for January 1979 through October 1980 for the Chesterfield County Airport site.

Comparisons of January-April and May-August rainfall demonstrate a greater difference between these periods in 1980 (Jan-Apr = 48.4 cm, May-Aug = 23.1 cm) than in 1979 (Jan-Apr = 49.3 cm, May-Aug = 46.2 cm). Whereas rainfall was nearly equal in the Jan-Apr periods, rainfall in the May-August period of 1980 was half that in 1979. In addition, unlike the other periods, which had greater than normal rainfall, the 1980 May-August period exhibited a net departure from normal of -21.2 cm. The combination of higher summer temperatures and the sporadic and reduced rainfall in the May - August period of 1980 resulted in the complete elimination of surface water for varying lengths of time in July and August that year. Standing water was present from the start of the study until 14 July 1980 when the area was first recorded as being completely dry.

Variation in late spring and summer weather induced variation in the phenology of breeding activities of the central Virginia anuran community (Figure 1, Table 1). The most important result of the weather-induced differences is in larval survivorship patterns. Larval survivorship occurred in both years for the early spring-breeding species, whereas survivorship was higher in 1979 than in 1980 for the summer-breeding species (Table 1). In fact, the larvae of *A. crepitans*, *G. carolinensis*, *H. femoralis* and *R. catesbeiana*, and, presumably, *H. chrysoscelis*, *B. woodhousei* and *R. clamitans*, exhibited zero survivorship in 1980.

### Discussion

Seasonal patterns of breeding and metamorphosis are common features of anuran communities in North America (e.g., Wright, 1932; Murphy, 1963; Heyer, 1979; Weist, 1982; this study), South America (Crump, 1974), Africa (Bowker and Bowker, 1979) and Asia (Heyer, 1973). The ecological basis for the seasonal succession has yet to be elucidated, however (Wilbur, 1980). In Virginia anurans are behaviorally, morphologically and physiologically adapted for breeding in late-winter/early spring and late spring/summer seasons. Variation in climate and weather patterns strongly affect

Table 2. Life history attributes of central Virginia anurans. Breeding periods are WS = late winter-early spring, SP = spring, SS = late spring-summer, SU = summer, F = fall. Habitat types are T = temporary and P = permanent. Larval period is the estimated number of days from egg laying to metamorphosis, and maturity and survivorship pertain to relative differences among species. Body size is the maximum snout-vent length in mm. A question mark indicates that insufficient information is available. All data are based on my Virginia field notes unless noted otherwise.

Species	Breeding Period	Habitat Type	Larval Period	Probability of Metamorphosis	Survivorship		Body Size ♂ / ♀	Maximum Clutch Size	Maturity
					Larval	Adult			
<u>H. crucifer</u>	WS	T	50	certain	low	low	31/34	1600	early
<u>P. brimleyi</u>	WS	T	50	certain	low	low	29/36	300 <sup>a</sup>	early
<u>P. triseriata</u>	WS	T	50	certain	low	low	31/32	600	early
<u>R. utricularia</u>	WS/F	T/P	80/270	certain?	low	high?	70/80	4000	delayed?
<u>A. crepitans</u>	SS	T/P	30	certain	low	low	23/26	200	early
<u>B. americanus</u>	WS	T/P	60	uncertain <sup>c</sup>	low	high	68/81	6100	delayed?
<u>B. woodhousei</u>	SS	T/P	50	uncertain	low	high	74/80	4500	delayed?
<u>H. chrysoscelis</u>	SS/SU	T/P	30	uncertain	low	high?	42/48	2600	delayed?
<u>H. femoralis</u>	SU	T	30	uncertain?	low	low?	36/40	1700	early?
<u>G. carolinensis</u>	SU	T/P	30	uncertain?	low	low?	29/32	1600	early?
<u>R. catesbeiana</u>	SU	P/T	360/720 <sup>b</sup>	uncertain	low	high	145/155	20000 <sup>c</sup>	delayed
<u>R. clamitans</u>	SU/F	P/T	90/334 <sup>d</sup>	uncertain	low	high	80/85	7000 <sup>e</sup>	delayed

a. Gosner and Black (1958)

b. Collins (1979)

c. Collins (1975)

d. Berven (1979)

e. Wells (1976)

actual dates of egg deposition, larval survivorship and other aspects of the life histories of these animals. General (seasonal) patterns, however, appear to be consistent. Extinctions of larval populations due to drought have been reported by Blair (1957) and this study. The effects of drought on survivorship of adult anuran populations are unknown.

Information derived from the two-year study of the Chesterfield Airport anuran community, coupled with other information (primarily Mitchell and Pague, unpublished), provides a summary (Table 2) of anuran life history strategies in central Virginia. Relative estimates of larval and adult survivorship and age at maturity stem from comparisons with information in Collins (1975) and inferences from my observations.

The twelve species of anurans studied here can be tentatively assigned to the two groups generally outlined by Collins (1975). Group I consists of Acris crepitans, Gastrophryne carolinensis, Hyla crucifer, Hyla femoralis, Pseudacris brimleyi, and P. triseriata. All are characterized by small body size, small clutch size, and early maturity. The three early spring breeders apparently have a good (certain) probability of surviving to metamorphosis each year. Because the springtime aquatic habitat appears to be predictable over time (pers. obs.), natural selection should favor anurans which reproduce early rather than those who delay maturity and risk a greater probability of mortality (Williams, 1966). The three summer breeders may have a reduced probability of metamorphosis depending on environmental conditions but partially compensate by possessing a short larval period. Although they reproduce in ephemeral habitats, these three species may possess attributes of delayed maturity, long life and relatively small clutch sizes. Selection should favor anurans with these attributes under conditions of extreme unpredictability of larval metamorphosis. This has been called the grandmother effect (Stearns, 1980). In this strategy an individual scatters her offspring over several breeding periods (seasons) so that at least one subset may encounter favorable conditions and survive to metamorphosis.

Group II consists of Bufo americanus, B. woodhousei, Hyla chrysoscelis, Rana catesbeiana, R. clamitans, and R. utricularia. These anurans are characterized by relatively large body size, large clutch size, and delayed maturity. Of these anurans B. americanus may have the best probability of metamorphosis because it breeds in early spring in aquatic systems which usually do not dry out until after the metamorphic period. Bufo woodhousei and H. chrysoscelis breed in late spring and summer often in temporary aquatic systems. They are the most likely species to experience an uncertain probability of metamorphosis, however they compensate somewhat by having a relatively short larval period. The three Rana species breed in permanent and temporary aquatic habitats in central Virginia. Survivorship of larvae to metamorphosis is tenuous in temporary systems and uncertain (because of increased probability of predation) in relatively permanent systems because of the long larval periods. Anurans living in environments such as these should be favored by natural selection to live longer and produce smaller, multiple clutches over several seasons (the grandmother effect).

Placement of A. crepitans, G. carolinensis and H. femoralis in Group I and B. woodhousei and H. chrysoscelis in Group II may not accurately reflect their evolutionarily derived life history strategies. Perhaps a third category based on the grandmother effect (see above) may be a more realistic approach. The ranids may also exhibit this effect but their inclusion is speculative because they apparently possess high reproductive effort, whereas the grandmother effect predicts a low reproductive effort (Stearns, 1980). Our problem may be the lack of knowledge of comparative reproductive effort values for anurans. The known clutch size for small-bodied anurans may reflect high reproductive effort, but the

known sizes for large-bodied species may not. We lack data for comparison.

A gradient of strategies may exist in actuality rather than two distinct groups, as in  $r$  and  $K$  selection (Pianka, 1983), depending on whether a population occurs in a permanent or ephemeral aquatic habitat. Gastrophryne carolinensis, for instance, breeds primarily in rain puddles but also in fish hatchery ponds (pers. obs.). Drying of the latter habitat may be unpredictable but may still provide a more permanent (longer term) habitat when compared to a rain puddle. We might expect G. carolinensis in a hatchery population to be larger, exhibit longer life, relatively later maturity, and perhaps larger clutch size than those in a rain puddle population. In ephemeral pools natural selection would be expected to favor a shorter larval period and individuals which metamorphose earlier (Travis, 1980; Emerson, 1986). Interpopulation variation in body size exists in several Virginia anurans (C.A. Pague and J.C. Mitchell, unpublished). This suggests other aspects of their life histories vary as well. Emerson (1986) suggested larval heterochrony is responsible for shape and size variation in anurans. Environmental conditions in ephemeral versus relatively permanent habitats are likely to induce developmental heterochrony in anuran larvae. This source of variation may be a key factor influencing differences in life history attributes among populations and may be partly responsible for within-species life history strategy gradients.

Accurate placement of the twelve Virginia anurans into the two groups of life history strategies as outlined by Collins (1975) has proven to be difficult. The most important problem is that we lack information on many key life history attributes for all these species. While some information may exist for some species on some attributes, geographic variation makes the use of that information tenuous at best.

The geographic location of a community under study is likely to affect the outcome of comparisons of larval and adult life history traits among species. Species density contributes to larval densities which in turn affect size, timing and probability of metamorphosis (e.g., Wilbur and Collins, 1973; Wilbur, 1980). Annual and seasonal variation in environmental factors affect key life history traits, such as survivorship. Subadult and adult survivorship vary greatly from site to site and year to year (Collins, 1975). Thus, comparisons like those made in this paper should be interpreted in light of the geographic and environmental conditions under which they were taken.

The foregoing discussion should be viewed as an exploration of the life history strategies of Virginia anurans. It establishes hypotheses about key life history attributes of each of the twelve species discussed herein. Future research elucidating these attributes would allow us to more accurately categorize anuran life histories.

#### Acknowledgments

Wendy Mitchell assisted me in all phases of the field work. Christopher A. Pague and George R. Zug assisted with fieldwork on two occasions. The Smithsonian Institution provided some field supplies. Chris Pague discussed life histories of anurans with me at length and he and Werner Wieland commented on the manuscript. This paper was prepared while supported by the Nongame Wildlife and Endangered Species Program of the Virginia Commission of Game and Inland Fisheries.

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## News & Notes

1987 ANNUAL MEETING  
VIRGINIA ACADEMY OF SCIENCE  
VIRGINIA JUNIOR ACADEMY OF SCIENCE  
MAY 19-22  
OLD DOMINION UNIVERSITY  
NORFOLK, VIRGINIA

### SPECIES OF SPECIAL CONCERN IN VIRGINIA

A SYMPOSIUM on "Species of Special Concern in Virginia" will be included as part of the Biology Session at the May 19-22, 1987 meeting of The Virginia Academy of Science. Researchers doing basic research on animals (vertebrates and invertebrates) in Virginia are encouraged to apply. Publication of the proceedings is anticipated.

For details contact:

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Department of Biology  
Radford University  
Radford VA 34142

(703) 831-5191

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### A N N O U N C I N G

#### MOUNTAIN LAKE BIOLOGICAL STATION

#### SUMMER FIELD COURSES 1987

<u>First Term</u>	<u>(June 14 - July 18)</u>	<u>Second Term</u>	<u>(July 19 - August 22)</u>
Ornithology	Kerry and Patricia Rabenold Purdue University	Community Ecology	Norman L. Christensen Duke University Henry Wilbur Duke University
Plant-Animal Interactions	Steven N. Handel Rutgers University Earl D. McCoy University of South Florida	Mammalogy	Gordon L. Kirkland, Jr. Shippensburg University
Plant Taxonomy	Spencer Tomb Kansas State University	Plant Population Biology	Keith Garbutt Harvard University
Workshop in Allozyme Techniques	Charles R. Werth University of Kansas		

Scholarships Available: Service Awards for students covering room and board costs  
Scholarships which provide financial assistance  
Post-Doctoral Research Awards (10 weeks)

For further information and application, write to:

Dr. Blaine J. Cole, Director  
Mountain Lake Biological Station  
Rm. B-64 Gilmer Hall  
University of Virginia  
Charlottesville, VA 22901



## Necrology

IN MEMORIAM

**DALLAS W. COCKE**  
(1940-1986)



Dallas W. Cocke died of complications from an aneurysm in the brain on December 6, 1986. Born in Richmond, Virginia, she was educated at The Collegiate Schools in Richmond. Her undergraduate degree was from Duke University in English and science in 1962. She obtained a master's degree from Virginia Commonwealth University in educational administration in 1974. She taught briefly in the school system of Henrico County, but most of her teaching career involved teaching biology to eighth grade students at The Collegiate Schools.

Dallas Cocke was a member of the Virginia Academy of Science for many years. During her tenure with the VAS, she served six years as a member of the Virginia Junior Academy of Science committee, four years as chairman of the fund raising committee, as a section chairman for the VJAS for several years, and coordinator of the VJAS's activities with the American Junior Academy of Science. In 1983, Dallas became director of the AJAS. The VAS elected her as a Fellow of the VAS in 1983. She was awarded the Distinguished Service Award from the VJAS in 1985.

Other recognitions that came to Dallas Cocke included being a Virginia winner of the 1983 Presidential Award for Excellence in Science Teaching, in 1986 receiving the Distinguished Service Award of the National Association of Academies of Science for her work with the AJAS, and in 1986 being elected an honorary member of the University of Richmond chapter of the national biology honorary society, Beta Beta Beta. She aided the Science Museum of Virginia in its early development stages by serving as chairman of the Discovery Room, as a fund raiser, and as a state traveling ambassador. She served other civic and church organizations.

Dallas is survived by her husband, Richard, a lawyer; one daughter, Mary Stuart, a student at the University of Virginia; a son, Michael, a student at North Carolina State University; her parents, Mr. and Mrs. Michael West of Richmond, VA; a sister, Mrs. Nancy Lee King of Springfield, VA.; and many friends through Virginia and the nation.

The Virginia Academy of Science will miss this good and faithful servant.

## NOTES

## NOTES

## MEMBERSHIP

Membership in the Academy is organized into sections representing various scientific disciplines as follows:

- |  |                                   |
|--|-----------------------------------|
| 1. Agricultural Sciences               | 9. Medical Sciences               |
| 2. Astronomy, Mathematics<br>& Physics | 10. Psychology                    |
| 3. Microbiology                        | 11. Education                     |
| 4. Biology                             | 12. Statistics                    |
| 5. Chemistry                           | 13. Space Science &<br>Technology |
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